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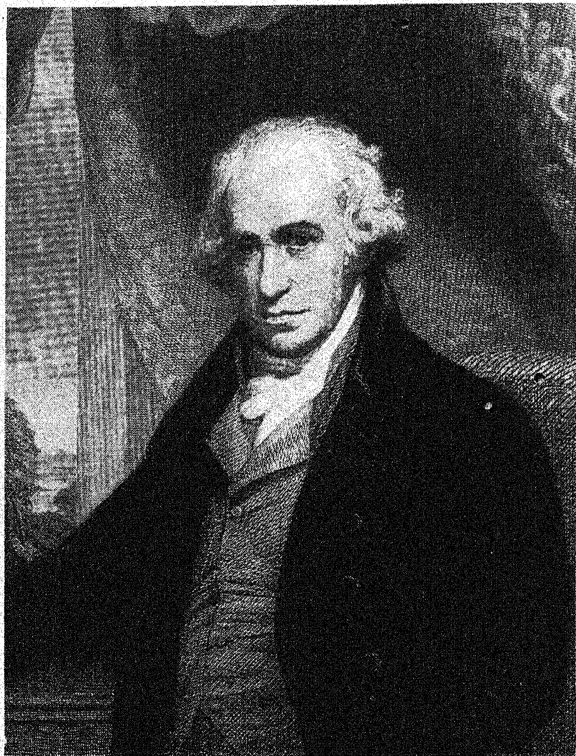

James Watt

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INDUSTRIAL BRITAIN

A SURVEY

BY

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AUTHOR OF
"THE GROUNDWORK OF MODERN GEOGRAPHY" "GREAT BRITAIN AND IRELAND"
"AN INTRODUCTION TO WORLD GEOGRAPHY" "JUNIOR SCHOOL GEOGRAPHY"
"THE BRITISH EMPIRE" "SOUTH LANCASHIRE" "THE ROMANCE OF THE COTTON INDUSTRY" (IN CONJUNCTION WITH L. S. WOOD M.A.) ETC.

WITH MANY ILLUSTRATIONS MAPS AND DIAGRAMS

NEW EDITION REVISED BY
L. R. LATHAM B.A.

GEORGE G. HARRAP & COMPANY LTD.
LONDON TORONTO BOMBAY SYDNEY

First published December 1930
by GEORGE G. HARRAP & CO. LTD.
182 *High Holborn, London, W.C.*1

New Edition, revised, published February 1939

MADE IN GREAT BRITAIN. PRINTED AT THE PITMAN PRESS, BATH

TO

THE MEMORY OF

MY LIFELONG FRIEND

ARTHUR WATSON

PREFACE

THIS book has been written for the mature student and the general reader. It is by a layman for laymen, and therefore touches the technology of industries only lightly. It is hoped that the professional man of any calling may find in it such a summary as will help him to understand how Britain earns her living. It may be that the worker in one branch may be helped by seeing the whole of our important industries brought together in one perspective. The student, the professional man, and the business man should realize how the continued prosperity of the country depends upon the harmonious working and the well-being of its manufacturing industries.

Readers in the British Empire overseas and in the United States of America may find interest in seeing what Britain is doing and how she stands in her industrial life, and in comparing her industries with their own.

A slight amount of repetition is inevitable in such a book, but it is better to say an important thing twice than to miss it altogether; it is hoped that the repetition is not such as to become wearisome.

The writer realizes the size of the task he has undertaken, and he can only hope that he has been quite fair in any criticisms and suggestions he may have made. He has been watching British industry sympathetically for half a century, as a one-time worker in two of its great manufactures, as a student and teacher, and for nearly twenty years as head of a technical school. He would realize a very high ambition if, by the present book, he could add to the prosperity of his country and the well-being of its workers.

Many friends have helped by giving information and advice. These the writer would thank most warmly here; and he would especially mention Mr T. B. Ecroyd, of Messrs

William Ecroyd and Sons, Ltd. (in whose mills the writer worked as a boy and young man for seven and a half years), Sir Amos Nelson, of Nelson, Lancashire (of which town the writer is a native), Mr J. B. Ellison, of Northside Mills, Bradford, Yorks, Mr W. Wilkinson, Principal of the Blackburn Technical College, Mr W. Munn Rankin, Principal of the Burnley Technical College, Mr J. W. Pennington, head of the Textile Department of the last-named college, Mr E. G. Parris, of the firm of John Dickinson and Co., Ltd., paper manufacturers, of Croxley and Hemel Hempstead, and Mr D. Greenhill and Mr A. G. Symmons, of the Sun Engraving Company, Ltd., Watford.

A. W.

NOTE TO THE NEW EDITION

Owing to the death of Dr Albert Wilmore in 1932 this new edition of his work has had to be entrusted to other hands. The revision, which has been carried out by Miss L. R. Latham, is confined mainly to statistics: the characteristic features of the book have been retained.

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INTRODUCTION

BRITAIN is predominantly industrial, and so long as the present world-order of things continues she must remain so. Not in the present or in the next generation does any serious change seem likely to take place. Britain will remain for a long time yet a maker of many things for sale, a shopkeeper for her own people and for the world. Two hundred years ago, in a simpler and less exacting age, she was much more self-supporting than she is at present, and she had little to sell to other people; but even in those days the demand for things which could not be grown here, for things which were not found in the rocks of Britain, and for many things which were not made in this country was becoming more insistent. The world will never go back to those simpler ages, and the demands of the nations become greater year by year.

The population of the British Isles at the present time (1938) is probably about 46,200,000; and many careful authorities estimate that Britain, from her own resources, could not feed more than about one-fifth of that number. This means that about 37,000,000 people must be supplied with food from abroad. Of course, it is somewhat beside the point at this day to talk about any nation feeding itself or being self-contained. It is easily possible to demonstrate statistically that the acreage of cultivable land in Great Britain is absolutely inadequate for the support of the population. This statement does not take into account the falling birth-rate; but neither does it make allowance for the loss of some of our best soil, much of which is rapidly being rendered agriculturally unproductive by building schemes, waste disposal (including burial-grounds), and water-storage works. Even the great food-producing countries of temperate latitudes, such as Canada, must import tropical produce.

Britain, however, is peculiarly dependent on other lands

for her food, both as regards quantity and variety. It is probably safe to say that four-fifths[1] of the food of her people is imported. And for variety of foods Britain has learned to depend upon many other countries. Considering only those foods which the climate will not permit Britain to grow, the list is a long one: maize, rice, sago, tapioca, tea, coffee, cocoa, cane sugar, groundnuts, olive oil, grapes, raisins, currants, citrus fruits, bananas, figs, dates; and many food accessories which are now almost necessaries, such as pepper, ginger, nutmegs, allspice, and others.

In addition to the above list there are many of the raw materials of industry which cannot be grown in the British Isles—cotton, jute, hemp, ramie, alpaca, mohair, silk, esparto-grass, piassava, sisal, vegetable oils of many kinds; timbers, such as ebony, mahogany, teak, jarrah, and greenheart; gums, resins, gutta-percha, rubber, camphor, tanning materials, indigo, and logwood. Some articles in this list, like cotton, vegetable oils, and rubber, are quite indispensable, while others are considered necessary, and all are desirable and useful.

The point of all this is to emphasize how dependent Britain is. On the other hand, it must not be forgotten that this country has a great purchasing power; and there is some satisfaction in knowing that it is precisely the immense purchasing power which has made her so dependent; she offers, on the whole, one of the best markets for the world's products, and she receives them.

The British are the greatest shopkeepers in the world, and it is necessary to maintain a great output to justify the vast and varied import of goods from abroad; in other words, all these varied things from abroad are bought by the productions and the services of the British people. This is the reason and the justification for the employment of a large proportion of the British people in mining and manufactures, and in the transport and sale of commodities which are made or obtained in Britain.

The people of Britain are thus driven back upon the great *basic industries*, which are so important in themselves, and

[1] Some would say five-sixths.

which are in turn the foundation of so many other profitable industries. There is, first of all, the famous and oft-quoted tripod of these fundamental industries, on which a vast superstructure has been built; this tripod is expressed in the familiar words—*coal, iron, ships*. It will appear abundantly in the sequel that, although there are many other industries which add enormously to the wealth and prestige of Britain, it is largely by these three great basic industries that in the present age Britain must stand or fall.

Coal represents power, heat, and a vast complex of wonderful things which are now used regularly in everyday life. Iron, together with its derivative, steel, is far and away the most important metal. Other metals are important, but iron surpasses them all, and many of the others now owe their own value very largely to the part they play in adding variety to the properties and uses of iron. Ships—big modern liners, tramp steamers, coasting vessels, wind-jammers—all these are more used by and are more necessary to the British than to any other nation. The people of Britain live in an age of coal, an age of iron, an age of ships; and, what is more, their well-being and prosperity depend upon these three things.

As an industrial people, British workers and shippers have certain great advantages, which may well be called important assets. A glance at some of these is desirable.

(1) There is Britain's great and varied mineral wealth. Consider coal first; taking into account its area, Great Britain possesses the richest and most accessible coalfields, containing the best coal of any region in the world. An Englishman might be suspected of undue patriotism if he wrote this; a distinguished American geographer is responsible for the statement. And, notwithstanding all that has been done to develop and harness water-power, and all the wonderful progress that has been made in oil-driven machinery, especially in regard to the internal-combustion engine, Britain still lives in the Coal Age. Britain also has great resources of iron ore, ores of many other metals, salt, building stone, slate for roofing, shale and clay for bricks and tiles, sand for glass, and limestone for many purposes.

(2) The British climate is eminently suitable for carrying

on manufacturing industries. It is neither too hot nor too cold, and it is very rarely that work must be suspended on account of the weather. There is sufficient variety in the weather and climate to keep man in first-rate condition too; and the average temperature is approximately that at which man's bodily and mental powers are at their best.

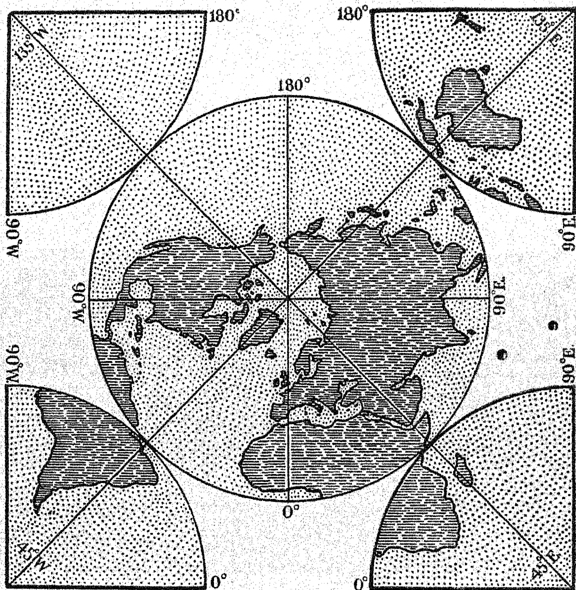


Fig. 1. Diagrammatic Representation of Britain's Central Position relative to the Major Land-masses of the World

(3) The world-position is fortunate, and the ports are easily reached. Britain lies nearly at the centre of the land-masses of the world. The seas by which the British ports must be approached are always open. There is no other region in the world in the same latitude of which this can be said. To revert to the shopkeeping simile again, the British shops and factories are in the centre of the populations who are their best customers, and are in the best possible position for the

delivery of goods and for buying stocks of raw materials and food.

(4) Last, but by no means least, are the historical factors. In modern industrial developments the British were first in the field, and though the early monopoly could not possibly have been maintained all human experience invariably records that intelligent pioneers must have some advantage. Britain built up a very great asset of 'goodwill,' due to a reputation for good work and straight dealing, and this asset should be jealously guarded by all who value their country's good name.

In this book the industries of mining, manufactures, and transport will be considered; their interrelationships, their dependence upon structure, topography, position, climate, and many other geographical factors; and, as a general rule, some mention will be made of the way in which historical development has influenced present position and may point the way to future success.

SECTION A

THE BASIC INDUSTRIES

CHAPTER I

COAL IN BRITISH INDUSTRY

One of the greatest problems of advanced industrial nations to-day is the supply of energy. This energy, in the first place, is usually produced in one of two forms—heat energy and mechanical energy, or power to do work. These are mutually convertible; heat energy, through steam, is used to do work, and also heat itself is often produced from other forms of energy. Thus in warming a room in Great Britain by means of an electric radiator the heat is produced by an electric current, the electricity has usually been generated by a steam-driven dynamo, and the steam was probably produced by the burning of coal.

Modern nations produce almost all their supplies of energy by burning either coal or oil, or from falling water. To some extent wood and peat are burned also. Coal is so important, and has so impressed the popular imagination, that falling water used for generating power is often spoken of as 'white coal' (*la houille blanche*).[1] The last-named source of energy is being more and more called upon, and Scandinavia, the Alpine countries of Central and Southern Europe, the eastern provinces of Canada, the Rocky Mountains states, New Zealand, and Japan are among the states which are in the forefront in the exploitation of this form of energy. The British Isles cannot hope to exploit water-power energy on anything like the same scale as Norway, Switzerland, Ontario, or South Island, New Zealand, though British sources should be neither despised nor neglected. Nor can

[1] See H. Cavailles, *La Houille Blanche* (Paris).

Britain hope to produce relatively much energy from her own almost negligible supplies of petroleum. She must continue, as in the past, to rely very largely on her coal. It is fortunate for her that she is so abundantly supplied with coal of good quality, not too costly to obtain, and so conveniently placed that it can be transported to other parts of the British Isles at little cost.

It was the fashion a generation ago to say that Britain was going through her coal resources very rapidly, and the writer remembers prophecies and warnings of the eighties and nineties which predicted that, in two or three centuries at most, the British coal resources would be used up. These prophecies, however, have turned out to be much too gloomy, and the position appears very different to-day. Nothing can possibly justify the wanton waste of either material resources or natural energy, and there is no doubt that the British have been exceedingly wasteful in the use of their coal. Waste is a relative term, and what may have seemed a fairly economical way of using coal a hundred or even fifty years ago may be regarded as almost criminally wasteful to-day. There can, however, be no question about the statement that the British ironmasters of the early days, the coke-makers and the gas engineers, were not sufficiently concerned about the wasteful way in which they were using coal. Nor can the ordinary old-fashioned open fire-grates of the home be forgiven, nor the almost universal use of them at the present day be condoned. The very high price of coal to-day, however, restrains the reckless usages of fifty years ago, when coal was so cheap that many people, rather than have the trouble of relighting the fires in their homes, kept them burning continuously. Such a practice seems scarcely credible to-day; it was by no means uncommon fifty or a hundred years ago.

The amount of coal obtained from the British mines has been carefully recorded since about 1870. From the records one sees how widely its use was extending in the latter part of the nineteenth century; the rate went up rapidly and constantly, with minor fluctuations. This can be simply expressed without using any great volume of statistics. In

round figures, the production of coal in millions of tons has been as follows:

Year	1860	1870	1880	1890	1900	1910	1913	1924	1934	1937
Millions of tons	80	110	147	182	225	264	287	267	221	241

The curve in Fig. 2 indicates quite clearly the continuous general increase until 1913. The year 1913 was the peak year, and, though prophecy is very hazardous in such mat-

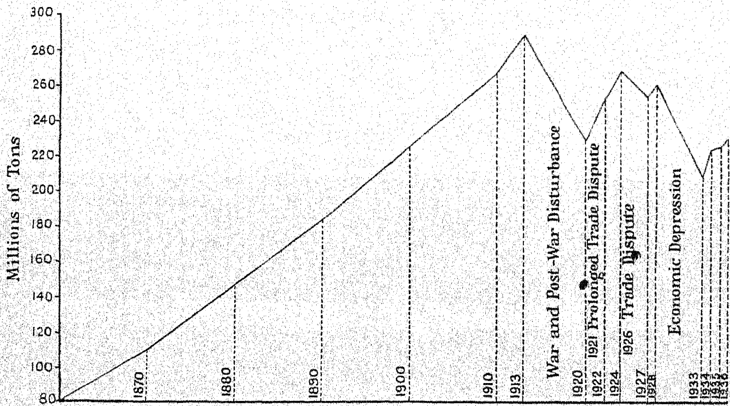


FIG. 2. GRAPH OF THE TOTAL COAL OUTPUT FROM 1860 TO 1936

ters, the amount of coal obtained in that year does not seem likely to be surpassed for some time, unless new processes employing coal are invented or old ones considerably improved.

It involves no serious error to reckon that in any normal week nowadays the production of coal in the United Kingdom is nearly 5,000,000 tons; the amount varies considerably from time to time, but that is a fair average week. This would mean nearly 250,000,000 tons per year,[1] the total depending upon the length of holidays allowed. What becomes of this coal? About 176,000,000 tons are burnt, as coal, in the natural state, in fire-grates and in boilers for raising steam. This includes roughly about 12,750,000 tons for railway locomotives, and 11,750,000 tons for

[1] Actually for the past four years it has averaged 220,000,000.

colliery engines. Nearly 40,000,000 tons are now carbonized either in coke ovens or in coal-gas works, rather more than half of this in the coke ovens and rather less than half in the gas-works. Between 50,000,000 and 55,000,000 tons are exported or sold as bunker coal. The two great *desiderata* at present are, first, to maintain at the present level, or even to increase, the amount exported, and second, to carbonize more coal before it is burned, and so to secure the valuable constituents which the carbonization process yields, and which are largely lost by combustion in open grates.

It may be helpful at this point to review and summarize the possible ways of using coal. It is burnt in the natural state to produce heat for domestic purposes, to heat water for circulation in the hot-water pipes of buildings, and to raise steam. The steam is sometimes used for heating buildings, but much more is required for generating mechanical power through steam-engines. These steam-engines act either directly or by the production of electricity, which latter may in turn generate light or heat or mechanical power. To use natural coal directly for the above purposes is now considered wasteful by many engineers.

By dry distillation, or carbonization, coal is converted into coke, gas, and tar, with the liberation of some other products, such as ammonia and sulphur. Broadly speaking, there are two kinds of coke, as commonly understood: (i) that produced in the gas-works, and usually known as gas coke, (ii) that produced in coke ovens, to be used for metallurgical purposes. The latter is used in blast-furnaces, steel furnaces, and foundries, and is generally held to serve that purpose better than coal. A solid product, sometimes known as semi-coke, 'coalite,' or by other trade names, is now being obtained by carbonization of coal at a lower temperature than that commonly employed until recently.

The problem before the engineers and chemists, backed by the educated opinion of the British people, is so to use the wonderful resources of coal in the country as to produce the maximum amount of useful heat, or steam, or electricity, and at the same time to obtain as much coke, gas, and by-products as possible.

Coal and its Occurrence

British coal includes several varieties. *Anthracite*, or *stone coal*, is a hard, stone-like coal, which does not soil the fingers on handling, and possesses a semi-metallic lustre. It is much less readily combustible than other kinds of coal, and burns with a smokeless and feebly luminous flame, leaving very little ash. The most important British source is the western part of the great coalfield of South Wales. *Bituminous coals* and *humic coals* include ordinary house coals, manufacturing coals, coking and coal-gas coals. These are all free-burning coals. There are transition types, known as semi-anthracite and semi-bituminous, which are good coals for steam-raising in ships, and they are usually known as steam-coals. *Cannel* is a dull black, lustreless coal, which has an irregular, splintery fracture. It burns with a smoky, candlelike flame, and often gives off a characteristic smell on burning. It occurs as lenticles or small irregular beds in association with bituminous coals. *Torbanite*, or *boghead coal*, is an exceptional kind, somewhat allied to cannel; it was mined at Torbane Hill, in Linlithgow County (or West Lothian), but is now practically worked out.

Coal occurs in layers, or seams, which often preserve approximately the same thickness over wide areas. In the British Isles these seams vary in thickness from a few inches to thirty feet. A seam under one foot in thickness is rarely mined, though coal from such a seam is often dug in open workings on some convenient hillside. Seams of one foot six inches to two feet are usually worth working unless access is difficult or much trouble with underground water is encountered. Most of the better-known British seams are from three feet to six feet in thickness. For example, the well-known Arley Mine of Lancashire is from three to five feet in thickness; it is actually known as the Marsden Four Feet in the north-east of South Lancashire. The Top Hard or Barnsley coal of the South-east Pennine Coalfield occurs over a district of 600 square miles; it is about five feet thick over very wide areas, although it comes down to three feet and goes up to eleven feet locally. The High Main or Wallsend coal of Northumberland is an historic seam, usually from

six to seven feet thick; it is now largely worked out in Northumberland. At Aberdare and Rhondda, in South Wales, some of the well-known seams are called the Four Feet, Six Feet, and Nine Feet respectively.

The floor, or rock, on which a coal seam rests is usually a greyish or dirty white clay known as the underclay, or 'seat,' but sometimes this seat is missing, and the coal rests on shale or sandstone or limestone. The underclay of a coal seam is generally a fireclay, because it is almost or quite free from alkalis and bricks made from it will stand high temperatures without fusing. The 'roof' of a coal seam is generally a shale or a sandstone, or other hard rock, but it may be a soft clay. The nature of the roof is an important factor in determining the difficulty and expense of working a seam.

In different parts of the world workable coal seams occur in every geological system, from the Devonian to the Tertiary; but in the British Isles there is little coal in any other system than the Carboniferous. There are thin seams in the Lower Jurassic of North-east Yorkshire and the Upper Jurassic of Brora, in Sutherlandshire. Local layers and pockets of impure lignite (an earthy, brownish coal) are found here and there in the Eocene strata of Southern England, and a thicker bed occurs at Bovey Tracey, near Newton Abbot, in Devonshire. These local and irregular occurrences are of little economic importance, though they are of great interest to the geologist.

The Carboniferous System is usually divided by geologists into two parts, Lower and Upper, each of which is in turn divisible into two formations; this general division is shown in the following table:

Carboniferous System	Upper, or Westphalian	Coal Measures
		Millstone Grit
	Lower, or Avonian	Yoredale Rocks and Pendleside Series
		Carboniferous Limestone

Generally speaking, almost all the workable coal seams south of a line drawn from Morecambe Bay to the mouth of the Tees

occur in the Coal Measures. In extreme North-west Yorkshire and in West Durham and West and North Northumberland some coal is mined from the Millstone Grit and the Lower Carboniferous. Coal seams in the Carboniferous Limestone become more important in Northumberland, north of Alnwick, and in Eskdale and Liddesdale, on the Solway side. In Central Scotland workable coal seams occur both in the lower and upper parts of the Carboniferous. This difference in the geological succession has had considerable influence on the industrial development of the region.

The Coal Measures occupy considerable areas in the British Isles; where they form the surface rocks and contain workable coal seams the district is termed a coalfield. A correct knowledge of the distribution of British coalfields is necessary for the understanding of much that follows in other sections, and the reader is recommended to pay particular attention to the accompanying maps in the following chapters. The coal-bearing strata pass under newer non-coal-bearing systems in several regions in the British Isles; such an occurrence makes what is termed a concealed coalfield. If the overlying strata are not too thick, and the 'concealed' coal seams are valuable, the latter are frequently worked by more or less deep shafts. The knowledge of the concealed coalfields of the British Isles has increased greatly during the last fifty years, and this knowledge has affected both the present position of the coal industry and the outlook for the future very considerably. There is still much research work to be done in this direction.

It may be well to remind the reader who has not studied geology to any great extent that coal seams form only a very small fraction of the thickness of the Coal Measures in which they occur. This formation is itself usually divided by geologists into three sub-formations, Lower, Middle, and Upper. In most parts of England and Wales the Middle Coal Measures yield by far the most coal; the Lower Coal Measures contain, as a rule, not more than two really good seams, and the Upper Coal Measures contain only thin seams of coal. But these generalizations do not hold everywhere, even in the British Isles.

As an illustration of the relation of the thickness of workable coal seams to the total thickness of the Coal Measures, the North-east Lancashire or Burnley Coalfield may be given. There the Upper Coal Measures are probably missing altogether, the Middle Coal Measures are well represented, and the Lower Coal Measures are thicker than in most regions. In a generalized vertical section through 2360 feet of Coal Measures there are twelve workable coal seams of a total thickness of a little more than thirty feet; the rest of the strata are shales, sandstones, and coal seams that are not mined.[1]

A seam of coal one foot thick yields about 900,000 tons of coal per square mile; this figure is generally used in the calculation of the quantity of coal available. The limitations of mining usually adopted are to take into consideration only those seams which are not less than one foot in thickness and not more than 4000 feet deep; the latter depth is at present considered the maximum depth at which coal can be mined. In 1913 Sir Aubrey Strahan, then Director of the Geological Survey, estimated the coal reserves of the British Isles at 178,277,000,000 tons. Two years later Professor H. S. Jevons estimated the reserves somewhat higher, his figure being 197,000,000,000 tons. Taking into account the amount used since these estimates were published, the mean of the two would now be about 172,000,000,000 tons. If the consumption continues at the rate of 250,000,000 tons a year it will be seen that British coal will last for less than 700 years from now. It is obvious that this estimate may need complete revision in future years.[2] New processes may be discovered that use considerably larger quantities of coal, and the annual consumption may increase again as it did until 1913. On the other hand, it is just as likely that less wasteful methods of using coal may take the place of those of to-day, just as Neilson's hot blast cut down the consumption of coal or coke in blast-furnaces a hundred years ago.

[1] See the author's *Groundwork of Modern Geography*, Chapters XI and XII (new and revised edition) (G. Bell and Sons, Ltd.).

[2] The Royal Commission on the Coal Industry (1925) confirmed the estimate that the accessible coal in seams of 1 foot or more in thickness and above 4000 feet will last for at least seven centuries.

Among other changes, the use of the open grate, which burns coal in the natural state, will surely become rare. The proving of the concealed Kent Coalfield and the further development of the South-east Pennine Coalfield within recent years may lead one to hope that similar discoveries may be made elsewhere, and that the *proved* resources of coal may thus be considerably increased. And, finally, new sources of energy may come into use, such as cheap combustible alcohols or other spirits or oils from equatorial or tropical vegetation; or it may be that the harnessing of the tides is not such an idle dream after all. Electricity is being generated from water-power on a considerable scale in North Wales, from the Falls of Foyers, in the Highlands of Scotland, and from the falls of the Shannon. These are important contributions to British sources of power; but we cannot call upon such sources of power from waterfalls as can Norway, Sweden, Switzerland, France, and Italy.

CHAPTER II

THE PENNINE GROUP OF COALFIELDS

THE coalfields of the British Isles may be regarded as occurring in five well-defined groups: the Central Scotland group, the Pennine group, the Central England and Welsh Marches group, the Armorican group, and the coalfields of Ireland.[1]

COALFIELDS OF THE PENNINES

There are six coalfields on the flanks of the Pennines, or obviously connected in position and relationship with the Pennine uplift. These are the West Cumberland Coalfield, the Northumberland and Durham Coalfield, the coalfield of Yorkshire, Derbyshire, and Nottinghamshire, the Lancashire and Cheshire Coalfield, the North Staffordshire Coalfield, and the little Ingleton Coalfield.

The West Cumberland Coalfield extends over about 180 square miles, mainly on land, partly under the Irish Sea. The visible coalfield extends from a little south of Whitehaven, through Workington and Maryport, past Aspatria, toward Wigton; this part is about ninety square miles in area. There is also a concealed part north of Maryport and Aspatria, underneath the Trias; an area of at least twenty square miles of this concealed part has been fully proved by borings, and the colliery at Brayton, situated actually on the Trias, works the well-known Yard Band coal of that coalfield. It may be that the concealed field extends to Carlisle on the one hand and to Silloth on the other, but this is still a question for the geologists. The coalfield has long been worked under the sea, and some mining operations are now carried on at a distance of four miles from the coast. The total production of the coalfield is less than 1·5 million

[1] No coal is mined in the Isle of Man or in the Channel Islands.

tons per annum, which is about equal to that of two of the larger Yorkshire collieries. There are over thirty collieries in existence nominally, but they are seldom all working at

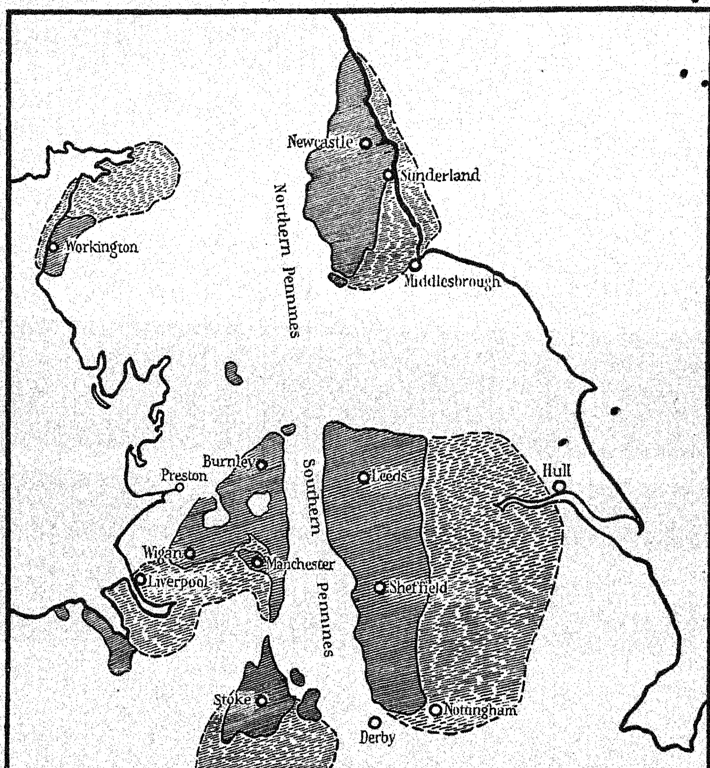


FIG. 3. SKETCH MAP OF THE COALFIELDS OF THE PENNINES AND THE PROBABLE EXTENT OF THE CONCEALED COALFIELDS (SHOWN BY BROKEN SHADING)

the same time. Some of them are small and employ very few men, but, on the other hand, a colliery at Workington employs over 1500 men and boys. It is to be hoped that the small collieries may be able to continue operations, even if the profits be only small.

The coal is mostly bituminous, and has been regarded as more suitable for household use, steam-raising in mills, and gas manufacture than for coke-making. It used to be said that there was little coking coal, but modern research has shown that some of it can be used quite well. A good deal of coke, however, has always come, and still comes, over the Pennines from Durham, for the blast-furnaces and steel-making purposes. The Furness iron district (which has no coal) receives little coke from West Cumberland, but 'imports' most of it from Durham, South-west Yorkshire, and Lancashire.

The Coal Measures of this small coalfield overlie the Millstone Grit, and under the latter is the Carboniferous Limestone, in which are many rich pockets of good hæmatite iron ore. If the coke problem can be fully solved, here in a very limited area there are four things concerned in iron-smelting —Millstone Grit for building, good ore, limestone for flux, and coal for coke. A good deal of hæmatite ore is imported from Spain.

The Northumberland and Durham Coalfield. Also called the Newcastle Coalfield. Conceive a triangle with a curved line drawn from Hartlepool to Barnard Castle as its base, its eastern side the coast of the North Sea from Hartlepool to the mouth of the Coquet, in Northumberland, and its western side a more irregular line from the apex to Barnard Castle again; this encloses the visible coalfield. The south-eastern part, a smaller triangle contained within the greater, has the Coal Measures concealed under the Magnesian Limestone; the boundary between the exposed and the concealed Durham Coalfield is a line from South Shields to a point on the river Tees about half-way between Darlington and Barnard Castle.

This is a most famous and historic coalfield. Coal is said to have been shipped from Tynemouth as far back as 1269, and from it 'sea-cole' has been sent to London for centuries. Within the last hundred years the 'colliers' of the Tyne have been among the best-known ships of the North Sea. Ships from that coalfield have carried coal to all parts of the world, but more especially to the countries round the North Sea and the Baltic. The river Tyne itself has always been a great

exporter of coal, and many men with long-established rights have had their keels or flat-bottomed boats on that river. The export of coal from the Tyne alone is about 20,000,000 tons in a normally good year. In more modern times the town of Blyth has been made almost a new port, well equipped with every modern device for rapid filling, for ready transfer from coal-truck to ship's hold. All the towns on Tyneside and the ports of Sunderland, Seaham, and the Hartlepools have taken a share in the export.

The Northumberland and Durham Coalfield offers for sale at home and for export coal for household, manufacturing, gas-making, and coking purposes, but it contains no anthracite. On the other hand, much of the Durham coal, more especially, is remarkably free from sulphur and phosphorus, and the coke from the Durham coke ovens is thus in great demand for the hæmatite blast-furnaces of Furness and West Cumberland. The coke from South-west Durham is also unusually hard and compact, which is another advantage. A good deal of coke is exported to other countries for use in iron and steel furnaces. About 5,000,000 tons of coke per year are produced from the coke ovens of the North-east of England; this total includes products from some coke ovens in Cleveland. The majority of the coke ovens in this region are of the by-product type, and the region is developing an extensive chemical industry for this and other reasons, as will be seen later. A few stacks of coke ovens are still of the old beehive type.

Some of the most important collieries have sunk their shafts through the Magnesian Limestone of East Durham to reach the concealed coalfield; this enables them to be near the coast of the North Sea. Many of the larger collieries are either near the coast itself or on or near one of the rivers Tyne, Wear, and Tees; hence there is not much expense in land carriage, and the colliery owners have an advantage over their Yorkshire competitors, for example.

Many of the more seaward collieries have extended their operations some distance under the North Sea. Already workings have been carried three miles out under the sea. The difficulty is to obtain adequate ventilation for the work-

ings, and miners have, also, to ride a good distance from the bottom of the shaft before they reach the face of the coal seam that is being worked.

The annual output of the two counties has reached 50,000,000 tons of coal per annum, which is close upon one-fifth of the whole output of the United Kingdom. Dr Walcot Gibson estimates the reserves from the Coal Measures of these two counties at about 7,700,000,000 tons, or about 140 years' supply at the present rate of consumption. This old-established coalfield seems to be much nearer exhaustion than the general average of British coalfields. Some of the colliery companies carry on operations on a very big scale. The Ashington group of collieries, which use Blyth as their port, employed about 9000 men and boys in 1936. The Londonderry group of collieries, on the coast of mid-Durham, employed over 7000 in 1936, and the Bedlington group over 5000 men and boys.

The Coalfield of Yorkshire, Derbyshire, and Nottinghamshire. Also called the South-east Pennines Coalfield. This great and important coalfield extends from slightly north of Leeds to Nottingham. It is all one coalfield, although it extends into three counties, and although the Government records are given under two heads. The same types of coal occur throughout, and the geological structure and sequence are the same. Leeds is on this coalfield, near its northern limit, Sheffield is almost in the middle, and Nottingham is nearly at the south-eastern corner of it. The position of these cities in relation to the exposed coalfield will help the reader to visualize its situation and extent. Other important mining towns are Rotherham, Barnsley, Wakefield, Doncaster, Worksop, Mansfield, Chesterfield, Staveley, Kirkby, and Sutton-in-Ashfield. The exposed coalfield is about twenty-five miles wide in the northern half and less than ten miles wide in the south. It is at its widest in the latitude of Wakefield, but there is not much change in its east-to-west extension until Rotherham is reached; south of that town it narrows, until in the latitude of Mansfield it is not more than ten miles in width.

The western margin of the coalfield lies on the eastern

slopes of the Pennines, and the beds generally dip eastward. The Coal Measures lie in ordinary sequence on the Millstone Grit in the west, but at the east of the visible coalfield they are seen to dip unconformably—*i.e.*, not in sequence—under the Magnesian Limestone. The general succession is the same as for the other Pennine coalfields—Carboniferous Limestone and Millstone Grit under the Coal Measures, and Magnesian Limestone or other Permian and Triassic rocks covering the extension of the coalfield. It is obvious that in all cases the buried or concealed Coal Measures may be worked by sinking shafts through the newer beds. Until about 1854 no pits had

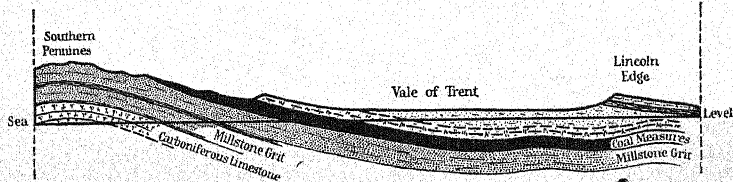


FIG. 4. DIAGRAMMATIC SECTION EASTWARD FROM THE SOUTHERN PENNINES, TO SHOW THE CONCEALED COAL MEASURES UNDER THE EASTERN PLAIN OF PERMIAN AND TRIASSIC ROCKS

been sunk in the region to the east of the visible coalfield, and it was tacitly assumed that the eastward dip of the beds would soon carry them to such depths that they could not be worked under the cover of the Permian and Triassic rocks.

A careful study of the dips in the visible coalfield shows that they are becoming more gentle toward the east, and when more and more pits were sunk later through the Magnesian Limestone it was apparent that the eastward dip was becoming more gradual and that the coal seams were not likely to be at depths too great to be mined. This is shown diagrammatically by the horizontal section in Fig. 4. The concealed or buried coalfield was thus seen to be within the limits of fairly deep mining, and within the last fifty years it has been increasingly reached and more fully known. The concealed field has been proved from Selby, in the north, to a few miles south of Nottingham; its eastern limits are as yet unknown. At first there was considerable hesitation at spending large sums of money in trial bores, and still greater

sums in sinking shafts, although that great pioneer geologist William Smith had stated more than a hundred years ago that the Coal Measures probably extended a long way under the Permian. The sinking of the Shireoaks pits in 1854, regarded at the time as a bold speculation, completely altered the outlook. At the present time there are thirty-eight boreholes and thirty-five collieries sunk through the cover of newer rocks. The boreholes show that, on the whole, the Coal Measures become deeper as they are traced eastward. A bore at Harby, east of the Trent, went down to 2310 feet below the surface, one at Crosby, north-east of Epworth, to 2970 feet, and the deepest of all, at Market Weighton, to 3100 feet, without reaching the Coal Measures. The most easterly collieries at present are those at Thorne, in Yorkshire, and Ollerton, in Nottinghamshire; that at Thorne is about three and a half miles farthest east. The Barnsley seam (the same seam as the Warren House coal of West Yorkshire and the Top Hard coal of Nottinghamshire) was reached at 2760 feet. The cost of boring and shaft-sinking, colliery plant, etc., has been well over a million pounds.

In the West Riding of Yorkshire the district round Doncaster is the most important part of the hidden coalfield, and the term Doncaster Coalfield is applied to that area. There the Barnsley seam is at a workable depth; to the north and north-east of that region the seams of workable coal decrease both in number and thickness.

The eastern limit of working in the concealed coalfield is not yet known, but the borings which have been made east of the Trent show that the top of the Coal Measures is at a depth of nearly 3000 feet in the north-west corner of Lincolnshire. The borings reached the Coal Measures at much less depths in the neighbourhood of Newark, and there is some ground for supposing that there may be even a slight rise of the coal-bearing strata south of Newark. None of the borings in the east of the known concealed coalfield has gone down to anything like the base of the Coal Measures.

The visible coalfield is the greatest single one in the British Isles, and the proved area of the concealed extension is considerably greater than that of the visible field; the total

area is about 2300 square miles. The whole field is thus by far the greatest in Britain, and it offers the advantage that its seams are less disturbed than in almost any other British coalfield. The total output of this great coalfield varies considerably from year to year, as does that of other coalfields, according to the state of general industry; of a total of 250,000,000 tons in the whole of Great Britain, an average output of a normal year free from industrial disputes in the coalfields, the share of the South-east Pennine field reaches nearly 75,000,000 tons, or 30 per cent. of the whole.

One of the famous seams has been mentioned, the Barnsley coal of South Yorkshire, called also the Top Hard and the Warren House; the thickness of this seam varies from three feet ten inches to thirteen feet one inch, but it is generally between five feet and nine feet thick. Another well-known seam is the Silkstone, of the Barnsley region, and "Silkstone Hards" have long been a favourite house coal in the North Country. The coals include household, manufacturing, coking, and coal-gas coal. Some of the coking coals are considered very good for the purpose, and there are many stacks of coke ovens; in fact, most of the larger colliery companies are also coke-makers. By-product plants are common, and many of the big companies are makers of tar, pitch, and sulphate of ammonia. The profits from the by-products are often greater than those from the coke itself. Again, some of the colliery companies are big concerns and employ many men. From 2000 upward is quite common; and the Brodsworth Main Colliery employed over 3700 in 1936.

The export of coal is not so great as that from the north-eastern and South Wales coalfields. The whole coalfield, visible and concealed, lies definitely inland, and the high railway rates have recently almost stamped out the export trade. It remains to be seen whether the rating relief proposals of the Government will re-establish the export of coal from Hull, Immingham, Goole, and Grimsby. In 1936 the Humber ports exported nearly 9 per cent. of the total exports of coal from the United Kingdom, against 35 per cent. from the north-eastern ports and 38 per cent. from the Bristol Channel ports. The Hull and Barnsley Railway, now a part

of the London and North Eastern Railway system, formerly depended in large measure on coal traffic from the Barnsley region to the ports.

The important mining centres Wakefield, Barnsley, and Chesterfield are on the visible coalfield; Doncaster and Mansfield, which are both some miles from the eastern edge of the visible coalfield, have within the last fifty years developed into great mining centres and coal exchanges.

A great many of the colliery companies are not only coal-producers and coke-makers, but they also own blast-furnaces, and in many cases steel furnaces also. A full-page advertisement of the activities of one of the great companies of the North, which recently appeared in a weekly commercial paper, may be quoted as a type. Their products, somewhat rearranged in order, are as follows:

Coal: For gas, coking, smithy, and bunkering.
Coke: Beehive and patent-oven coke for blast-furnace and foundry work. Coke nuts, coke breeze, and coke ballast.
Pig-iron: Hæmatite iron and foundry pig-iron.
Steel: Siemens-Martin open-hearth steel; ship, boiler, and chequer plates, sections, joists, and bars, slabs, blooms, and billets.
Silica and fireclay bricks and shapes: For use in steel- and iron-work, coke ovens, and gas-works.
Coke-works' by-products: Sulphate of ammonia, crude benzol, solvent naphtha, raw heavy solvent, toluol, etc.; refined tars and bitumen mixtures; pitch, creosote, etc.

The coke is specially advertised as "low in sulphur and ash and of great mechanical strength."

The Lancashire and Cheshire Coalfield. This coalfield lies on the western slopes of the Pennines and extends into the western plains. It is obvious that it was once continuous with the Yorkshire Coalfield. This is shown by the presence of small outliers, as at Baildon, north of Bradford, and Laneshaw Bridge, east of Colne; also by the fact that some of the coal seams in the two fields are almost identical in character

and succession, although differently named. Perhaps the best example of identity of seams is that of the one always known as the Lower Mountain Mine in Lancashire, and as the Halifax or Ganister coal in the West Riding. The two coalfields have been separated by the almost complete removal—by long-continued denudation—of the Coal Measures from the summit of the Pennine anticline.

The Western coalfield consists of three somewhat distinct regional divisions, the Burnley Coalfield in the north, the South Lancashire Coalfield, and the narrow East Cheshire extension. The coalfield is bounded on the north and east by the Millstone Grit, and no concealed extension may be expected in that direction. On the west and south the visible coalfield is bounded by the Permian and Trias, and it is quite likely that the coal-beds continue under the South Lancashire and Cheshire plain, to come up again in the neighbourhood of the Dee. The little patch of Coal Measures at Neston, in the Wirral, suggests this. The dip of the Coal Measures is so high on the south side of the South Lancashire visible field and on the west side of the East Cheshire extension that it is very probable the good seams will soon reach a depth of over 4000 feet, and so pass out of the reach of present-day mining operations. Of course, there are some collieries near the border of the visible field whose shafts pass through the red sandstones of the Permian and Trias, but any considerable extension of mining operations away from the visible coalfield is at present considered unlikely.

The Burnley Coalfield lies in a syncline, with the Pendle range of hills on the north and the Rossendale anticline to the south; this anticline brings up the Millstone Grit to the surface and accounts for the existence of the Rossendale Fells, which are so important in the industrial life of East Lancashire. The amount of fairly pure, soft water which comes out of the sandstones of these Millstone Grit moors is enormous, and has played, and still plays, an important part in the development of the chemical, paper, soap, bleaching, dyeing, calico-printing, spinning, and weaving industries of Lancashire.

The Lower Coal Measures are of considerable importance

in the Lancashire Coalfield, especially in the Burnley Coalfield, and the Lower Mountain Mine plays an important part in Lancashire mining and other industries. This seam and the Upper Mountain Mine are extensively worked in North-east Lancashire. The Middle Coal Measures yield by far the greater part of the coal, however, and the Arley mine at the base of the Middle Coal Measures has been a great source of wealth to Lancashire; this mine is known as Little Delf at St Helens, Orrell Four Feet in the Wigan district, and Royley, or Rowley, in South-east Lancashire. An interesting local development is the well-known Wigan cannel, which occurs in the middle part of the Middle Coal Measures. The cannel seam is a local phenomenon, and the thickness of cannel coal decreases in every direction from Wigan. It is interesting to note that lenticles, or local patches, or seams of cannel, occur at about the same level in the West Riding, in North Staffordshire, and in North Wales. The Wigan cannel coal is now almost exhausted, but there is not the demand for it that there once was. It was formerly sold in large quantities to the gas-companies for the enrichment of gas; the introduction of the incandescent mantle practically killed this trade.

The Lancashire and Cheshire Coalfield yields good house coal, manufacturing coal, and coal for coking; in the Burnley basin the Lower Mountain Mine is widely used for the production of coke. There is an immense demand for boiler slack and other forms of small coal for the cotton-mills, the engineering establishments, and the varied chemical industries. Hence Lancashire sends little coal to other parts of England, but brings in a good deal, especially from the West Riding and North Derbyshire. There is not a great volume of export to other lands, but the Belfast district has long had a connexion with the Burnley collieries, and the writer has known some of the well-known Burnley coals to be retailed at lower prices in Belfast than in Burnley itself.

Some of the collieries deserve special mention. The Pendleton Colliery, near Manchester, is exploiting a seam called the Rams Mine, at a depth of over 3500 feet. At the Fairbottom Colliery, near Oldham, James Watt (Boulton and Watt)

erected one of his earliest steam-pumping engines. The Bridgewater Collieries, at Worsley, are of great historic interest. The third Duke of Bridgewater came to reside on his Worsley estate in 1757 or 1758. Here were rich seams of coal, and the Duke conceived the idea of making a canal from his mines to Manchester, which was the nearest good market for the sale of coal. Brindley made the famous Worsley Canal, which was opened on July 17, 1761. The Duke, true to his word, reduced the price of coal at Manchester from one shilling to fourpence per hundredweight. This was one of the most important events in the history of transport and in the development of modern industry.

Francis Egerton,
Third Duke of Bridgewater

The annual output of this coalfield is now slightly less than 15,000,000 tons; and it has been going down for some years. The total reserves are estimated at about 4,000,000,000 tons, but it is suggested by many experts that one-quarter of this would be very costly to work. Hence the future life of this coalfield will probably be not so long as that of some of the other coalfields of Britain. Many of the best seams are nearly worked out over wide areas.

The chief mining towns are Wigan, Bolton, and Oldham, in the southern part of the coalfield, and Burnley, in the northern part. Manchester has a coal exchange. As pointed out already, an anticline brings up the Millstone Grit in the middle of East Lancashire, and there is, in consequence, a belt of moorlands in the middle of the coalfield in which there is not much coal-mining.

The North Staffordshire Coalfield. Also called the Potteries Coalfield. This coalfield lies at the south-western corner of

the Pennine uplift. It is connected with the Lancashire and Cheshire Coalfield by a narrow extension of the latter from Stockport, through Poynton and Pott Shrigley, to Macclesfield; the North Staffordshire Coalfield extends into South-east Cheshire, near Congleton. The coalfield now under consideration is roughly triangular in shape, with the apex of the triangle in the north; and it covers about a hundred square miles. There are also three smaller fields in North-east Staffordshire. The largest of these is the Cheadle Coalfield, which is about five miles long by four miles wide; two others, still much smaller, lie north-east and north-west of the town of Leek. They are, however, of little importance commercially.


James Brindley

The main coalfield is very important geologically, because it contains a full and typical sequence of the whole of the British Carboniferous system of rocks. The Coal Measures include a succession of Lower, Middle, and Upper Coal Measures, which is often taken as a type with which to compare the coal sequence in the other Pennine and Midland coalfields. The Upper Coal Measures are poor in coal, but contain some blackband ironstones which are still worked; the Middle Coal Measures contain all the main coals of that sub-formation, and here, as a rule, the seams reach their maximum thickness and are of good quality; the Lower Coal Measures are not as well exposed as in North-east Lancashire. The Coal Measures reach a maximum thickness of 7000 feet.

The coalfield contains thirty seams of coal of over two feet in thickness, showing an aggregate thickness of 140 feet of

coal, and these can all be worked in the district at a depth less than 4000 feet. The seams produce house, manufacturing, coking, and blast-furnace coals. The Hard Mine coal of the east of the coalfield contains little ash and scarcely any sulphur; hence it is highly prized as a blast-furnace coal, and is much used instead of coke for that purpose. The reserves of coal in seams of over one foot in thickness and less than 4000 feet in depth amount to over 4,000,000,000 tons.

The clays, shales, fireclays, and marls of the Coal Measures in this coalfield are used for the manufacture of pottery and sanitary ware. The district is often known as the Potteries, and the coalfield is frequently named the Potteries Coalfield; this is due to the great development of the pottery and sanitary ware industries on the coalfield. Stoke-upon-Trent, Hanley, Burslem, Tunstall, and Longton produce vast quantities of these wares. It should be pointed out, in considering the industries of the region, that the iron, steel, and engineering industries employ a larger number of men than the earthenware manufactures.

The blackband ironstone of the upper part of the Coal Measures has been mentioned above. The ironstone occurs in irregular bands and nodules. Clinging to the nodules, and interbedded with the ironstone bands, there is generally plenty of carbonaceous matter; this enables them to be calcined without the expenditure of any additional fuel before the ore is taken to the blast-furnace.

Some of the big companies whose works are in the district own collieries, by-product coke ovens, blast-furnaces, Siemens-Martin steel furnaces, and rolling-mills for steel. One coal-mine in this coalfield employed about 3200 men in 1936.

The Ingleton Coalfield. This is a small coalfield in the north-western part of the West Riding of Yorkshire, where the Coal Measures have been let down between two of the great Pennine faults—the Dent Fault and the Craven Fault, which intersect not far away. The little coalfield is bounded by the Millstone Grit of the Bowland Fells on the south and western sides. The beds consist of Lower and Middle Coal Measures, partly concealed under Permian rocks. The succes-

sion of the strata does not correspond with that of the other Pennine coalfields, and the view is generally held that this little coalfield is a fragment of an area of deposition that was detached during the Upper Carboniferous period. The Coal Measures are there about 1500 feet thick, and three seams were worked until 1936, the Four Feet, the Yard coal, and the Six Feet. The Nine Feet seam is abandoned. The coalfield is in the form of a quadrilateral, with the greatest length about six miles and the width about four miles. Three hundred and forty men were employed on the coalfield in 1929, and the mine produced gas, household, manufacturing, and steam coal.

CHAPTER III

THE COALFIELDS OF CENTRAL ENGLAND AND THE WELSH MARCHES

THESE coalfields are treated together simply for convenience, and not because of any suggestion that they are genetically connected and structurally separable from the others. The seven coalfields here grouped are: the North-west Leicestershire (Ashby-de-la-Zouch), the North-east Warwickshire, the South Staffordshire, the Forest of Wyre, the Coalbrookdale, the Shrewsbury, and the North Wales. The North-west Leicestershire Coalfield has many affinities with the Derbyshire and Nottinghamshire Coalfield, and the North Wales Coalfield is similar in many ways to the coalfields of South Lancashire, Cheshire, and North Staffordshire.

The North-west Leicestershire Coalfield—also called the Ashby-de-la-Zouch Coalfield, because this town is in the middle of it—extends also into South Derbyshire. Its visible area is about twenty-four square miles, but there are concealed extensions workable through the cover of Triassic rocks in the south-eastern and western parts of the field. There are twelve separate collieries, and the amount of coal produced per year is a little over 2,500,000 tons. The coal is used for steam generation and as house coal. This small coalfield is within 120 miles of London, and a good deal of its coal is sent by rail to the capital. The best-known coal seam is the Main Coal, which is between five feet and seven feet thick in the north of the field, but by coalescing with another seam in the south it becomes fourteen feet thick. The field is estimated to have a reserve of 1,825,000,000 tons, or about 600 years' supply at the present rate of output. Ashby and Coalville are the principal mining centres.

The North-east Warwickshire Coalfield. This coalfield has affinities with the North-west Leicestershire Coalfield in some respects and with the South Staffordshire field in others.

There is no Carboniferous Limestone or Millstone Grit under the Coal Measures, and in this characteristic it differs sharply from the Pennine coalfields, but is similar to the southern part of the South Staffordshire field. The Lower Coal Measures, or Ganister beds, are probably absent too, and the Coal Measures seem to begin with the Middle series. A

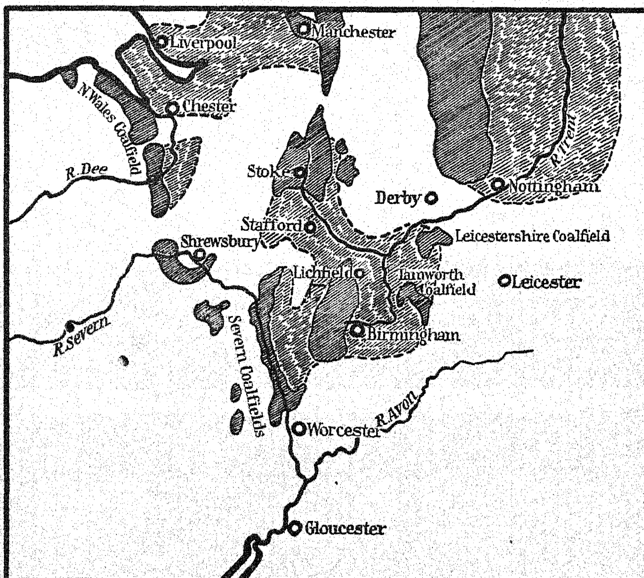


FIG. 5. THE COALFIELDS OF CENTRAL ENGLAND AND THE WELSH MARCHES

considerable area of the visible coalfield is occupied by a thick series of barren beds in the Middle Coal Measures. There is a remarkable coalescence of workable seams in one part of the field, and at Newdigate Colliery probably five seams coalesce to form the Hawkesbury Thick Coal, which is over twenty-three feet in thickness, including three clay-shale partings. The visible coalfield extends from near Tamworth in a south-south-eastward direction to within about five miles of Coventry. The concealed coalfield is already exploited through the Permian and Triassic rocks. Exhall Colliery,

for example, is on the Permian at some distance from the south-western edge of the visible coalfield.

The coalfield is somewhat spindle-shaped, covering an area of about 150 square miles; the annual output is about 5,500,000 tons, and the total reserves are estimated at about 1,126,000,000 tons, or 240 years' supply at the present rate of output. The coalfield yields good house and manufacturing coal, and as most of the pits are not far from the old London and North Western main line a good deal of coal is sent to the London market. Much coal is also sent to London and district by the Grand Junction Canal (now part of the Grand Union Canal).

The South Staffordshire Coalfield. This coalfield, though not of great extent, is famous in many ways. The visible coalfield is about twenty-five miles in length, reaching from near Rugeley, in the north, to south of Halesowen; its shape is somewhat like that of a thick spindle, with its greatest width about nine miles almost in the latitude of Wolverhampton. The greater part of the field is in Staffordshire, but about one-fifth of it, the section from Dudley southward, is in Worcestershire. Near the edge of the visible coalfield, but outside it, are Birmingham, Stourbridge, Rugeley, and Lichfield. Walsall and West Bromwich stand mainly off the coalfield, but their western suburbs overlap it. Dudley, Wednesbury, and Bilston are important towns on the middle of the coalfield.

The visible coalfield is about 150 square miles in area, and appears on the map as an island of Coal Measures surrounded by Permian and Triassic rocks. The coal-bearing beds extend from the visible coalfield under the red sandstones and marls of the surrounding region, and the concealed extension is of considerable area. Many colliery shafts have been sunk through the newer rocks, and the concealed coal seams have been reached and are now worked, often at great depths. The earliest of these shafts was sunk at Sandwell, two miles beyond the boundary of the visible coalfield in South Staffordshire, where the famous Dudley Thick seam was reached at a depth of 1250 feet. Trial borings were put down in various other regions, and the presence of the concealed coal-

field proved. Now the underground extensions are worked chiefly in four principal directions and regions; in the Cannock Chase region in the north, toward Lichfield in the north-east, toward Birmingham in the south-east (where the coal-workings are now found on the western fringes of the great city), and at Wolverhampton in the west.

The visible coalfield mainly consists of an anticline whose extension is roughly north to south, and whose limbs slope off to east and west in basins which disappear under the cover of the newer rocks. The basin arrangement is so well developed that it is customary to speak of the Wolverhampton Basin in the west and of the West Bromwich Basin in the south-east. These basin-like extensions have proved of very great importance in the industrial development of the region.

The whole coalfield is quite unlike the Pennine coalfields in the relation of its coal-bearing beds to the underlying strata. The North Staffordshire and the Lancashire Coal Measures rest on Millstone Grit, below which, again, is the Carboniferous Limestone. In the Cannock Chase locality these formations are but poorly developed, and in South Staffordshire and North Worcestershire they are wanting; the Coal Measures there rest directly on a floor of Silurian rocks. These older rocks come to the surface in the neighbourhood of Walsall and Dudley; in the latter region the famous Wren's Nest of Wenlock limestone has been of great interest in the history of geology. The limestones of the Silurian system have played a great part, too, in the growth of the iron-smelting industry, as they furnished in the early days a ready flux quite close to the coal and the blackband ironstone.

This occurrence of iron ore, coal (for coke), and limestone as a flux in such close proximity was very important over a century ago. As soon as modern blast-furnace practice had established itself the making of pig-iron became a great industry in South Staffordshire. When Cort introduced the puddling-furnace in the latter part of the eighteenth century the production of malleable or wrought iron also became a great industry. In the first half of the nineteenth century

these South Staffordshire industries were in great vogue, and it was then that the name "Black Country" was given to the region, and the name was richly deserved. There were only just over a score of blast-furnaces at the end of the eighteenth century; the number had increased to about 180 by the year 1860. At that time this region produced quite 15 per cent. of the total pig-iron output of Great Britain. This was the day of furnaces with open tops, before furnace engineers had realized how much was being lost by their wasteful methods. During the daytime dense clouds of smoke belched out of these furnaces, and by night the same clouds showed their accompaniment of lurid flames. Much natural coal was used in the furnaces at that time, and this increased the lurid effect. These "Black Country" times are even yet spoken of as being the palmy days of the South Staffordshire iron industry. But at what a price!

The iron industry has declined, however, and the district has survived the change; instead of producing the primary product, pig-iron, in such large quantities the region has learned to regard it more as a raw material, which it uses in the innumerable metal industries for which it is famous. The furnaces no longer send out their lurid flames and their dense smoke. Most of the little furnaces of those early days have gone, and the furnaces that remain are of a larger type. The gases are now trapped and carried down to the chambers in which the blast is heated, or they are used for driving the gas-engines by which the blowing-plants are worked.

There were, on an average, seventeen blast-furnaces at work in 1911 in the whole of Staffordshire, Worcestershire, Shropshire, and Warwickshire, and in 1938 the number had dwindled to eleven. It may be of value to analyse the main causes of this decline. The early advantages were, of course, the plentiful supply of coke, the presence of iron ore and limestone, and the ease with which brown iron ore could be brought from North Staffordshire and, later, the Jurassic ores from Oxfordshire, Northamptonshire, and Rutland, by canal at first, and then by rail. Now the coal resources have diminished very greatly; the upper seams have long been

worked out, and deeper mines are more troublesome and expensive. Again, coke rather than coal is now the common smelting fuel—though South Staffordshire still uses some coal—and the local coal does not 'coke' well, and supplies have to be brought from Yorkshire and other regions; this means greater expense. The local, native ironstone has to be supplemented very considerably from other sources. The cost of transport is now too great for the less efficient furnaces to bear, and they have been steadily crushed out. In reviewing the whole situation, one wonders rather that so much of the industry has survived than that there should have been so serious a decline.

Although so much coal has been won from this coalfield, the district has still great reserves awaiting exploitation. The southern part of the region made much of its early wealth by working the famous Dudley Thick coal, the Ten Yard seam of those days. This has been one of the most famous of British seams of coal. It occurs in South Staffordshire and Worcestershire, but not in the northern Cannock Chase region. A well-known fault, or system of faults or fracture-lines, the Bentley Fault, extends across the coalfield from east to west in the latitude of Walsall, and the succession of beds north of the faults is different from that to the south. There are several good seams in the northern area, and, as already mentioned, these have been proved in the concealed coalfield also. The Dudley Ten Yard seam is largely worked out in the visible field, but it occurs in the concealed basins on the east and west, and probably on the south, and only awaits mining development.

A great factor in the early and long-continued importance of this region has been the presence of many railways and canals. Birmingham is the greatest canal centre in the British Isles, and in the coalfield region north-west of that city canals have played a great part in its development. Though the importance of canals has declined since the coming of railways, they are still widely used for the conveyance of coal, coke, iron ore, pig-iron, and other heavy and less expensive materials associated with industry and everyday life. These canals will be mentioned again in a subsequent chapter.

Three great main lines of railway cross or touch the district. The old main line of the London and North Western passes immediately east of the coalfield, from Rugby, through Nuneaton, Tamworth, Lichfield, and Rugeley, and sends off its well-known and very important loop through the heart of the region from Rugby, through Coventry to Birmingham, and forward to Dudley Port, Wolverhampton, and on to Stafford. This is now a part of the London, Midland, and Scottish system. Another important line of the latter system is the old Midland Railway branch from Derby, through Burton-on-Trent, Tamworth, and Birmingham, to Worcester; this line passes through and serves the south-eastern corner of the industrial region. From this line there is a branch from Burton through Lichfield to Walsall, and from there to Wolverhampton, or Birmingham, or Dudley; this branch serves the very heart of the coalfield. A third main line is that of the Great Western Railway from Leamington and Warwick, through Birmingham, West Bromwich, Bilston, and Wolverhampton, to the north-west; this line also runs through the busy heart of the coalfield. There are also many other 'cross country' branch lines linking up the various towns of the busy industrial region.

It will thus be seen that this comparatively small coalfield, with an annual output of about 6,700,000 tons only, has gradually gathered to itself one of the busiest industrial regions of Great Britain, with a variety of metal manufactures that is unequalled in any other part of the world, and with most highly developed and complex means of transport and communication.

The Forest of Wyre Coalfield. This coalfield is of little importance economically, but it is geologically interesting. It is similar to several of the coalfields of France, for example, in that it was apparently formed by the filling up of old, irregular rock-basins of pre-Carboniferous age with Coal Measures. The main coalfield extends from the Abberley Hills, in Worcestershire, under the Forest of Wyre, to near Bridgnorth, in the narrow valley of the Severn. The coal-bearing beds lie on the Old Red Sandstone strata, and are overlapped on the eastern side by the Permian and Triassic beds.

The names of the divisions of the Coal Measures here illustrate very well the importance that was attached to sulphur in coal in the early days of iron-smelting—an industry for which the district was once famous. The Upper Coal Measures are called the Sulphur Coal beds; the Lower Coal Measures are the Sweet Coal group. Some of the coals from the latter beds—that is, from the lower beds—are used for household and manufacturing purposes; these seams are worked by shafts which pass down through the overlying Sulphur Coal series. Abberley is the most important mining centre in this small coalfield.

Two small outliers of coal-bearing beds lie well up on the Clee Hills of Shropshire; these are possibly remnants of a formation which once had a wide extension, and were, perhaps, connected with the Forest of Wyre beds. These small outliers are covered by cappings of hard, basaltic rock, and it is probably to the resistance of this hard rock that the preservation of the Coal Measure outliers is due. The coal seams are worked by shallow shafts and adits. The larger outlier is on Titterstone Clee, and covers an area of about four square miles; the smaller one is north of this, on Brown Clee, and is about two square miles in area. These two small fields have little economic importance, except quite locally.

The Coalbrookdale Coalfield. The Forest of Wyre Coalfield is about two-fifths in Worcestershire and three-fifths in Shropshire. In the north it narrows to a band less than a mile in width, and somewhat west of Bridgnorth connects with the southern extension of the Coalbrookdale Coalfield. This field, as far as the visible part is concerned, has a triangular outline, with the base on the middle valley of the Severn and its apex near the little town of Newport, in East Shropshire.

This small coalfield covers about eighteen square miles only, so that, again, it is not of great importance for the weight of coal produced; but it is of considerable interest historically. The great geologist Sir Joseph Prestwich wrote an elaborate memoir on this coalfield, published in the *Transactions* of the Geological Society of London, and often mentioned as a model of what a good memoir should be.

The coalfield is also famous because of the part it played in the early development of the iron industry.

Prestwich showed that the beds of this small field were remarkable for the variations they undergo within narrow limits. The coal seams are more than usually subject to lateral change—that is, as they are followed from one part to another. Probably here is a good example of the transition from the South Midland to the North Midland type of Coal Measures succession.

Sir Joseph Prestwich

By courtesy of the Geological Society of London

This little coalfield was most vigorously worked in the early days of organized coal-mining. A north to south fault, called the Lightmoor Fault, traverses the field, and when Prestwich was surveying the district in the eighteen-forties he pointed out that the area west of the fault was now almost destitute of coal. Professor Edward Hull, who wrote about the coalfields of Great Britain in 1861, said:

> The coal over a very large part of this field has been nearly exhausted, as will be apparent to anyone who crosses it by the Wolverhampton and Shrewsbury railway, where, over a large area, nothing but dismantled engine-houses and enormous piles of refuse from abandoned coal- and iron-mines meets the eye.

Hull estimated at that time that the amount of coal left for future use was 15,000,000 tons; the coal has been worked for seventy years since Hull wrote that estimate, and the present estimate of reserves is about 150,000,000 tons. This shows how much more is now known about the British coalfields than was known in the middle of the nineteenth century.

This field was the one in which Abraham Darby and his successors worked out the use of coke for the smelting of iron; and at Ironbridge there was in use until recently the famous bridge erected by Abraham Darby, the first iron bridge

ever erected. It was here, too, that John Wilkinson put on the Severn the first iron barge, and greatly astonished the coal-owners and ironmasters of his day. There are many small mines in this coalfield which only find employment for from five to ten men each; there are larger coal-mines at Highley, Lilleshall, and Madeley.

The Shrewsbury Coalfield. There are two patches of Coal Measures in mid-West Shropshire, and the two together form a sort of triangle, with the apex near Shrewsbury itself and the other angular points at Church Stretton and where the Severn leaves Montgomeryshire to enter Shropshire. The whole area is about twenty square miles, but the Coal Measures are of no great thickness, and the total reserves are estimated at only 38,000,000 tons. The whole of Shropshire yielded 680,000 tons of coal in 1936; this total included the yield from the Shrewsbury, Clee Hills, and Coalbrookdale Coalfields, and from some parts of the Forest of Wyre and North Wales Coalfields.

The North Wales Coalfield. This field is economically much more important than those in the valley of the Severn just considered. It stretches almost continuously from the Point of Air, in Flintshire, through that county and through East Denbighshire to south of the town of Oswestry, in North-west Shropshire. It is thus over forty miles in length, and it has a width varying from three miles to six miles. There are extensions and outliers in the Vale of Clwyd and across the valley of the Dee at Neston, in Cheshire (see p. 40). The visible coalfield occupies an area of about eighty square miles; the concealed extension on the eastern and northern sides may connect with the coalfields of North Staffordshire and South Lancashire, under the cover of the Permian and Triassic rocks and the drifts of the Cheshire Plain.

The output of this field amounted to 2,976,000 tons in 1936. It produces good steam coal, gas coal, house coal, and ordinary manufacturing coal. In times past one of the seams yielded large quantities of cannel coal, which was worked for gas manufacture and for obtaining a paraffin oil. The coming of the incandescent mantle killed the cannel-mining, as mentioned in connexion with the Lancashire and Cheshire Coalfield.

The district has been associated with iron-smelting since the very early days of the use of coke. The John Wilkinson already mentioned had works at Bersham and Brymbo. There are to-day blast-furnaces and coke ovens of the by-product type at Brymbo; and there are furnaces which make manganese steel at Mostyn. Hull mentions that in one year (before 1861) 12,560 tons of blackband ironstone were raised for the Brymbo furnaces. The well-known Minera limestone quarries supplied much limestone as flux for these and other iron furnaces. The limestone occurs throughout practically the full length of the coalfield, and its outcrop is never far away. This is another of the British examples of regions where, in the early days, coal, iron ore, and limestone were found close together, often in the same township. Very little iron ore is now obtained from the Severn valley and North Wales coalfields; the furnaces depend in the main upon foreign ore and ore from the Jurassic belt of England.

The North Wales Coalfield is served by two important main lines of railway: the London and North Western line from Chester to Holyhead and the Great Western line from Shrewsbury through Wrexham to Chester and Birkenhead. Near the entrance to the Vale of Llangollen are two of the most famous aqueducts in the country; they were built by the great engineer Telford, to carry the Ellesmere branch of the Shropshire Union Canal over the rivers Dee and Ceiriog respectively. That canal played a great part in the development of the southern part of the coalfield in the early days.

CHAPTER IV

THE SOUTHERN OR ARMORICAN COALFIELDS IN GREAT BRITAIN

THIS group includes the coalfields of South Wales, the Forest of Dean, Bristol, Somerset, the concealed Kent Coalfield, and the little-known coalfield of South-western Ireland. The last-named will be considered in a brief description of the coalfields of Ireland. The folds of the Pennine series of coalfields and those of the Midlands have their axes mainly north and south; the folds of the Southern group run east and west. These folds belong to a system which is well seen in the coalfields of Northern France and Belgium and farther east in the Ruhr Coalfield of Germany. The same system of folds is seen in the coalfields and in the other rocks of Southern Ireland.

At the close of the Carboniferous period there was a very different Europe from that of to-day. An epoch of intense earth-movements followed, and a large part of middle Western Europe was ridged up into a mountain range. The pressure force came from the south, and the mountains extended in a west-east direction. The flexures of these mountains were called Armorican by Professor Suess of Vienna. The name Armorican comes from the ancient name for Brittany, a region which was subject to the folding movements mentioned. Farther east similar flexures are seen in the old Variscan mountains of Germany. The geologist Bertrand called the whole of the folds the Hercynian system, from the ancient name of some of the mountains in Germany. In consequence of the intense earth-folding that then took place the rocks that are older than the Coal Measures are sometimes found to be thrust over the latter; this result may be seen in South Wales, in the Mendips, and in the valley of the Meuse, in Belgium. In the latter region the older Devonian and Lower Carboniferous rocks are seen to be thrust over the Coal Measures in the neighbourhood of Liége.

It was the similarity of the folding in the coalfields of South Wales and the Mendips to that seen in Belgium that led the British geologist Godwin-Austen, in 1855, to suggest that the Armorican system of coal-beds in South-western Britain might be continued under the Mesozoic and Tertiary rocks of Southern England, a bold suggestion and prediction which has been triumphantly vindicated in the proving of the concealed coalfield of Kent.

The coalfield of Glamorgan and district is by far the greatest of this Armorican group. The eastern part of this great field is in Monmouthshire, and the Coal Measures occupy all that county west of Pontypool. The largest division of the coalfield is in Glamorgan; a small portion is in the extreme south of Brecknock, and a considerable part in the west is in Carmarthenshire. This South Wales main coalfield is the third largest in the British Isles, both in area and in output of coal. The detached Pembrokeshire portion, west of Carmarthen Bay, will be considered apart. The main coalfield is about fifty-six miles from east to west and has a maximum width of nearly twenty miles in Glamorganshire. It is deeply indented by Swansea Bay and the Llwchwr (Loughor) Estuary, including Burry Inlet. The great feature of this coalfield is its basin shape of Coal Measures bounded on all sides by the Millstone Grit, the Carboniferous Limestone, and the Old Red Sandstone, except where the sea has cut these out on parts of the south side. The Millstone Grit, the Lower Carboniferous, and the Old Red Sandstone on the north side form the high ground of the hilly region which there bounds the coalfield. The siliceous sandstones and conglomerates of the Millstone Grit form the inner encircling zone of uplands, and it is from this zone that so many rivers flow across the coalfield.

The rivers have cut somewhat deep valleys, whose directions lie transverse to the east-west axis of the basin. These roughly parallel valleys have determined the position of many of the colliery shafts and of the mining towns. Many adit levels are opened up on the slopes of the steep-sided valleys, and shafts are sunk on the plateau surfaces which lie between pairs of parallel valleys. The general tilt of the region is from north to south, and the gradients of the railways are usually

from the north of the coalfield toward the sea. The coal-trucks are thus cheaply hauled from pit to port. This is one of the reasons why the South Wales Coalfield is the greatest of the exporting coalfields in Great Britain, as will be shown in Chapter VIII.

There is a remarkable general change in the lithological character of the coal from east to west. The coals in the

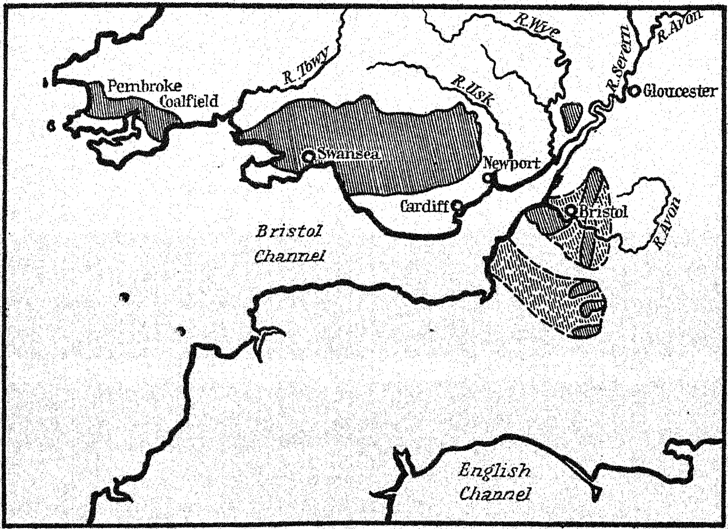


FIG. 6. THE ARMORICAN COALFIELDS OF ENGLAND AND WALES

east are mainly bituminous, but westward, on the whole, the volatile constituents gradually become less. In the middle of the coalfield the coal is largely semi-anthracite, and is highly prized as steam coal. In the west, in Carmarthenshire, anthracite predominates, and Swansea and Llanelly are the chief towns exporting anthracite.

The bituminous coals of the coalfield are used for domestic purposes, for manufactures, and sometimes for gas manufacture; the steam coal mainly for steam-raising on ships; and the anthracite for the same purpose, and for malting, hop-drying, and for stoves in the home and the office. Some

of the semi-bituminous coals are bought largely for use in railway engines.

Before the Great War South Wales had almost a monopoly of 'first class' Admiralty steam coal, and those firms which were on the Admiralty list, and on the lists of foreign Governments, were able to secure good prices. The use of oil-fired boilers has of late years caused a big cut in the demand for these Welsh steam coals. In 1913 the Royal Navy purchased over 1,500,000 tons of steam coal, but in 1926 little more than 250,000 tons.

Steam coal and anthracite accounted for fully three-quarters of the coal exported from Britain in 1936. Almost all the anthracite was from South Wales; the steam coal was, of course, shared by the other coalfields.

The total output of the South Wales and Monmouthshire Coalfield, including the Pembrokeshire extension, was 36,000,000 tons in 1936, and it was thus third in output, following the South-east Pennine and the North-eastern Coalfields. The total reserves of the whole field (including Pembrokeshire) are estimated at over 26,000,000,000 tons, so that at the present rate of consumption (which tends to fall rather than to rise) the supply may last for about 600 years; but, of course, as in all other coalfields, if and when the coal becomes nearly exhausted it will be more difficult to get and the cost will be relatively greater.

The Coal Measures of South Wales fall into three series, Upper, Middle, and Lower; but it is not suggested that these correspond exactly with the three divisions found in North Staffordshire, for example. The division is a local one, and is adopted as being suited to the region. The Lower series is often called the Steam Coal series; the Middle group is usually known as the Pennant series, from the presence of the thick beds of sandstone called Pennant sandstone. All the divisions contain coal seams of workable value. Some of the more famous of the seams are the Nine Feet Vein, the Great Vein, the Furnace Vein (up to twelve feet thick), the Rock Fawr, the Swansea Six Feet, and the Swansea Four Feet. The whole Coal Measures series reach nearly 10,000 feet in thickness.

The anthracite coals are restricted to certain areas, as already pointed out, a phenomenon which has led to a great deal of discussion. At least four distinct geological or mineralogical explanations have been put forward, but objections to each of them can be readily adduced; hence in the present volume the fact of the strictly local distribution will be considered sufficient, and the problem of origin left to the further discussions of the geologists.

The county of Glamorganshire produced 230,000 tons of iron ore in 1936; some of this was from the Carboniferous Limestone of the rim of the coalfield, and some of it from the Lower Coal Measures. The layers of ironstone, locally known as veins, are seldom more than four inches in thickness; analyses of typical samples show from 26 per cent. to 40 per cent. of iron. In the early days of the iron-smelting industry this ore attracted the attention of ironmasters, and in the first part of the nineteenth century the iron industry was almost as important as the coal industry. Very soon the yield of the local ores from the Coal Measures and the Carboniferous Limestone became insufficient, and a large import trade soon grew up; by 1850–60 a steady trade in Northamptonshire ore had been established. Later this supply was supplemented by a vigorous import of Spanish hæmatite.

There have been considerable changes in the iron industry on this coalfield since the middle of the nineteenth century, when Mr R. Hunt prepared his much-quoted *Mineral Statistics*. There were 147 iron furnaces in blast in 1858, nearly all of them in the bituminous coal district—that is, toward the east of the coalfield—and the amount of pig-iron produced in that year was nearly 900,000 tons. The relatively small furnaces of those days have since been replaced by furnaces of much greater capacity. There were twenty-three furnaces in being in 1927, but on an average only eight were in blast,[1] yet the amount of pig-iron produced was 739,000 tons, which included 610,000 tons of hæmatite pig, 115,800 tons of basic pig, and 11,000 tons of foundry pig-iron. It will be noticed that though the number of furnaces looks ridiculously small compared with the number in blast seventy

[1] Five were usually in blast in 1937.

years ago, the amount of pig-iron produced is not so much lower as might have been expected. The diminution was nearly 18 per cent.

The frequently repeated statement that South Wales coal does not make good coke is not borne out by a consideration of the figures for 1936; the South Wales Coalfield, including the little Forest of Dean Coalfield (which cannot make a great difference) was the third region in Great Britain for the production of coke, coming after the North-east of England and the Yorkshire, Derbyshire, and Lincolnshire coking region. There were 7044 coke ovens in use on the average in 1936, and less than 10 per cent. of these were of the old-fashioned beehive type. Anthracite and best steam coal are not coking coals.

The Welsh ironmasters, almost all of whose works were on the coalfield, turned their attention to steel-making in 1864, when the Bessemer process was introduced at Ebbw Vale. For some years after that date Spanish ores continued to be imported in large quantities; they were often mixed with British ores, and the South Wales steel-makers were very prosperous. The rise of Middlesbrough, and the plentiful supply of Cleveland ore, available there and in Durham, hit the South Wales iron industry rather hard. The Welsh furnaces were up among the hills, many miles from the coast; for every ton of pig-iron made the steel-maker had to haul two or more tons of iron ore up to near the coal outcrop, and when he had made steel rails or steel plates there was also the cost of carriage to the coast again. The handicap was too great, and the famous Dowlais works (founded in 1757) were brought down to the sea at Cardiff, away from the coal altogether, but close to port facilities. Steel-making, both of the acid and basic types, is still a great industry in connexion with this coalfield, even if all the modern works are not actually on it. The Statistical Appendix to the Government returns does not give the steel output of Great Britain strictly in relation to the coalfields, but it is readily discernible that South Wales and Monmouthshire take a very high place, having produced over 20 per cent. of the steel of the country in 1927. The South Wales and Monmouth-

shire Coalfield depends very largely upon the Great Western Railway Company, one of whose main lines runs through the region. By the Railway Act of 1921 this company has absorbed a number of local railways which served the heart of the coal region, and which come down the valleys to meet the main lines of railway. The whole system makes one of the most effective railway networks in the country.

The Pembrokeshire Extension. Across Carmarthen Bay to the west is the Pembrokeshire Coalfield, which extends like a band through the region to St Brides Bay. The rocks are very much contorted, as may be seen all round the coast, from Pendine Sands to Milford Haven. The Coal Measures themselves are seen to be much disturbed in coast sections north of Tenby. The coals are either anthracite, or of the nature of culm, or comparatively worthless small coal. In travelling across this coalfield from Haverfordwest to Tenby one would scarcely suspect that the Coal Measures were there at all. No coal-pits with their winding gear and other equipment are seen; the evidences of Coal Measures have to be searched out, and many of the inhabitants seem to be quite ignorant of the presence of coal. The explanation is that the strata are so contorted that it would be difficult and very expensive to work any seams satisfactorily on the normal scale. Then, too, most of the seams are thin, and would not pay for the sinking of shafts. The workings are few, and are confined to shallow pits. In 1936 the total yield of the coal in Pembrokeshire was only 39,874 tons.

The Forest of Dean Coalfield. This is a small coalfield, which has a most interesting history. It lies between the valleys of the Severn and the Usk, and shows geological features which are transitional between the great coalfield of South Wales and the little coalfields of Bristol and Somersetshire. The coalfield appears on the geological map as a heart-shaped exposure of Coal Measures surrounded by a narrow inner ring of Millstone Grit and a wider outer ring of Carboniferous Limestone, the whole resting in a basin on a foundation of Old Red Sandstone.

The coalfield has an area of over thirty square miles, and is estimated to contain 250,000,000 tons of coal in reserve.

The whole output is not much more than that of one of the larger Yorkshire or Durham pits, and yet 1,440,000 tons of coal (the amount of the output in 1936) is not to be despised. The coal is used for household and manufacturing purposes, and for coal-gas manufacture. The old mining rights are peculiar to the region. A person born there, who has worked in a coal-mine for a year and a day, becomes a 'free miner' and has an exclusive right to work coal in any part of the Forest which is not already occupied by other miners. This partly explains why there are so many small mines where less than ten men are employed. Many of the small mines have interesting and suggestive names, such as Mousetrap, New Found Out, Farmer's Folly, and Pluckpenny. The High Delf coal is the most important seam; several large collieries at Lydney, Coleford, and Cinderford work this seam. In 1936 these collieries found work for several thousand men and boys.

The Carboniferous Limestone rim contains hæmatite iron ore, which occurs in some dolomitic beds. The output of iron ore from the whole of Gloucestershire in 1927 was 2375 tons, though in 1936 the amount was negligible.[1]

Coleford and Cinderford, whose names betray some of the past history of the region, are the chief mining centres. The region is still well forested, and the scenery is very fine on the western side, especially where it approaches the beautiful Wye Valley.

The Coalfields immediately east of the Severn. There are six detached areas of Coal Measures in South Gloucestershire and North Somerset. The largest of these is the Bristol Coalfield, which extends from the Bristol Avon north-west, past Chipping Sodbury, to Wickwar; the five small coalfields of Somerset lie within a ring formed by Bristol, Weston-super-Mare, Wells, Frome, and Bath.

The Bristol Coalfield is partly bounded by the Millstone Grit and Carboniferous Limestone, but it is also partly concealed by a cover of Lias and Triassic strata. The small Somerset coalfields are all seen to disappear under the Mesozoic rocks. Coal-mining in Somerset is chiefly carried on

[1] It was reported that only three men were at work.

under the newer rocks, and as one travels over the beautifully varied and fertile country between Bath and the Cheddar cliffs there are seen the very occasional shafts of coal-pits which have been sunk through the Mesozoic rocks to reach the concealed Coal Measures beneath. The chief mining areas in Somerset are in the far north, near Bristol, and at Nailsea and Radstock; the Radstock Coal Measures are largely covered by Triassic sandstones and marls and the strata of the Lower Jurassic. Radstock itself is not on visible Coal Measures, but stands almost at the junction of Liassic and Lower Oolitic rocks.

Few of the known coals of Somerset have been worked, partly because many of the seams are thin and are composed of inferior coal. A few of the thin seams, however, are of good quality, and these are worked. The output of the whole of Somerset was 747,000 tons in 1936, which is, of course, much less than that of many a large pit in one of the big coalfields.

The visible Bristol Coalfield seems larger on the geological map than all the small visible fields of Somerset added together, but it still counts as one of the smaller coalfields of Great Britain. It produced only 106,000 tons of coal in 1936, or one-fourteenth of the quantity produced by the Forest of Dean, for example. On the railway journey across the lowland of Gloucestershire, east of the Severn, after passing through the Old Sodbury Tunnel and Chipping Sodbury, the traveller passes a station called Coalpit Heath, and here there are seen the usual winding-gear of a coal-pit and the huge banks of earth generally found near a coal-mine. Other mining centres are East Bristol and Lydney. There is no great development of industrialism on that part of the coalfield.

The Coalfield of East Kent. It has been mentioned already that a series of folds runs from west to east through the South of Ireland, Pembrokeshire, South Glamorgan, and Somerset, to reappear again in the North of France and in the Meuse Valley, in Belgium. The whole folded system includes not only the exposed coalfields of Kerry, Cork, and Limerick, South Wales, the Forest of Dean, Bristol, and Somerset, but also the partly concealed coalfields of Flanders, the Campine,

Dutch Limburg, and Germany north of Aix-la-Chapelle. The rocks of North Devon are also involved in these folds, as are also the similar strata of the Ardennes, in Belgium. It was almost inevitable that geologists should postulate the probable occurrence of similar basins concealed under the Mesozoic and Tertiary rocks of the South of England.

It was fifty years after the first suggestions of the geologists had been made that the first borings proved the existence

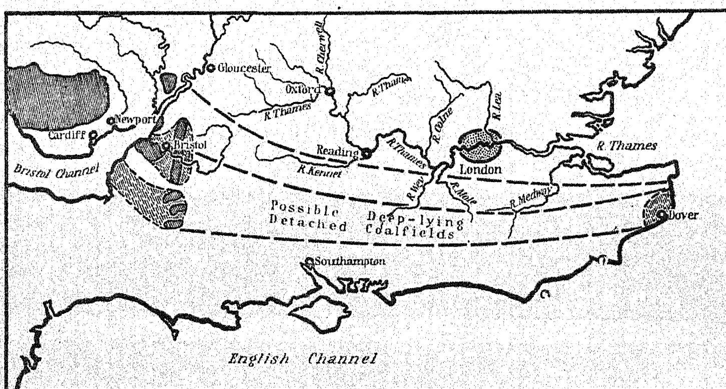


FIG. 7. DIAGRAM MAP SHOWING THE POSSIBLE LINE OF THE CONCEALED COALFIELDS OF THE ARMORICAN SYSTEM, FROM SOUTH WALES TO THE DOVER CONCEALED COALFIELD

of a concealed coalfield in East Kent. About twenty-five borings have been made within the last thirty years in an area contained by Ramsgate, Deal, Dover, Folkestone, and Canterbury; four colliery shafts are now sunk, and four collieries are working. The concealed coalfield is in a state of rapid development, and in 1936 it turned out 2,193,000 tons of coal. The Tilmanstone Colliery, which works a five-foot seam as a coal-gas, manufacturing, and steam coal, employed 1040 men in 1929. The Chislet Colliery, near Canterbury, which also works the five-foot seam, employed 1160 men.

The area of the concealed coalfield is estimated at over 200 square miles, beneath a cover of newer rocks not much more than 1000 feet in thickness. The amount of coal in

reserve has recently been estimated at over 2,000,000,000 tons. It is evident that as this coalfield is developed a new aspect may be given to the industrial life of South-eastern England.

It may be that some day coal will be reached similarly under the cover of newer rocks in the counties which lie in the line of the Armorican folding, between the Gloucestershire and Somerset coalfields in the west and the concealed coalfield of Kent in the east. Coal has been proved by borings at Burford, in Western Oxfordshire, and at Lemington, north of Moreton-in-the-Marsh, in North-east Gloucestershire. Another boring at Westbury, in Wiltshire, has reached the Coal Measures. It is therefore known that coal occurs in certain regions under the newer rocks, but whether in paying quantities or not is quite another matter. This question can be settled only by extensive exploration by means of borings.

CHAPTER V

THE SCOTTISH COALFIELDS

In the *List of Mines in Great Britain and the Isle of Man*, issued in 1929, there is mentioned a small coal-mine near Brough, in Westmorland, where seven men were employed in working an eighteen-inch seam of coal. The locality is in the Carboniferous Limestone region of the Northern Pennines. It is well known that as this formation is traced northward along the Pennine moorlands the limestone becomes interbedded with sandstone and shale, and that here and there a local coal seam occurs. These coal seams of the Northern Pennines occur below the Millstone Grit. They increase in thickness and importance northward, and in Northumberland many of these Carboniferous Limestone coals are worked. In the valley of the North Tyne the Plashetts seam is four feet six inches thick, and yields a good household and gas coal, which also cokes well, but the sulphur content is high. In the Scremerston group of Lower Carboniferous rocks, in North-east Northumberland, there are many workable seams, of which the Cooper Eye (two feet to four feet thick) and the Black Hill, or Scremerston Main, are perhaps the best known. Scremerston is a small town in North-east Northumberland, three miles south of Berwick.

Broadly speaking, south of the latitude of the Tees very little coal is obtained from beds below the upper Millstone Grit. Between the Tees and the Tyne Gap a little coal comes from the lower beds, and north of the Tyne Gap there are important coal-beds in the Lower as well as in the Upper Carboniferous.

In Scotland the workable coal seams occur in the Carboniferous Limestone and also in the Coal Measures formations, and in this particular they are quite unlike the Carboniferous rocks of Central and Southern England and Wales. The Carboniferous Limestone coals of Scotland are much more

important than those from any part of the North of England, but they are still less important than those from the Upper Carboniferous (the Coal Measures).

The true Coal Measures occupy many distinct basins, but it will be convenient here to reduce them to three principal groups and one small outlying coalfield, and then to divide one of the groups into two subdivisions.

The chief coalfields lie entirely between the two great structure lines that extend almost parallel to each other across Scotland from north-east to south-west; these structure lines are the Highlands Boundary Fault and the Southern Uplands Boundary Fault respectively. All the features of Central Scotland run, in general, from north-east to south-west, and follow the same main direction as the boundary faults. In broad outline, these geological and physical features are: (1) Strathmore, or the great Old Red Sandstone plain which extends from Stonehaven to Helensburgh; this is a fertile rolling country, in which sandstones and conglomerates of the Old Red Sandstone age are covered with a variable but generally thick mantle of glacial and other recent deposits. (2) Next comes a line of volcanic hills which can be traced from Montrose to Largs; the chief groups of these are the Sidlaws, Ochils, Campsie Fells, and Renfrew Heights. The reader will notice that these groups are separated from one another by the three rivers Tay, Forth, and Clyde. North-west of these hills no coal occurs. (3) Next in order southward is a broad belt of Carboniferous rocks intermingled with various volcanic intrusions and old lava-flows; this broad Carboniferous belt stretches from Fife Ness to Troon and Ayr, and is the region of the densest population in Scotland, because here are the coalfields. (4) To the south is a narrow and somewhat variable belt of Old Red Sandstone country which can be traced from Turnberry, in the west, to near Cockburnspath, in the east. This belt is a lesser edition of the Old Red Sandstone belt of Strathmore, and is much more irregular and broken up by various igneous rocks.

The wide belt of Carboniferous rocks is the part that concerns the present study. These rocks lie in a basin between the line of volcanic hills and a second line of hills to the

south, less well defined and more irregular. The basin is mainly occupied by two chief members of the Carboniferous system—namely, the Lower and Upper Carboniferous respectively. The Lower Carboniferous consists of a sandstone series at the base, followed by the limestone series, which

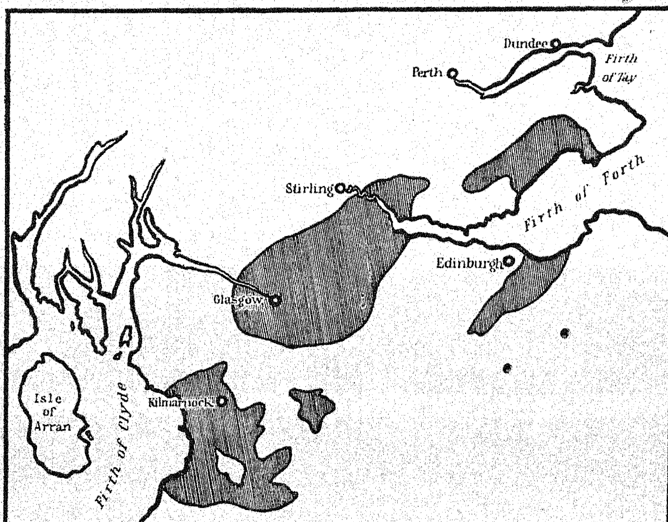


FIG. 8. DIAGRAM MAP OF THE COALFIELDS OF CENTRAL SCOTLAND

contains coal seams, as already mentioned. There is then a diminished representative of the thick Millstone Grit of Central England, followed by the Productive Coal Measures, which in turn are often covered by some barren Red Measures of the Upper Carboniferous system. The accompanying diagrammatic map shows approximately the regions occupied by the Carboniferous Limestone series and the Coal Measures. The reader may be reminded again that both the Lower and the Upper Carboniferous may contain workable coal seams in Scotland. These representatives of the old geology of the region are more or less covered by variable glacial and other recent deposits.

The economic importance of the beds demands for them a somewhat closer study of the general succession. It is best to begin at the base of the system. The sandstone series at the base in the middle-eastern part of the basin contains the famous beds of oil-shale (see page 73) and some thin seams of coal. The limestone series is generally divided into Lower, Middle, and Upper. A few workable coal seams occur in the Lower and Upper groups, but it is the Middle Limestones which contain the most important coal seams, and here also are valuable beds of blackband ironstone.

The Millstone Grit series is often known as the Moor Rock in Scotland. There are few workable seams of coal, but in Ayrshire the series furnishes the excellent and well-known fireclays of that county.

The Coal Measures series consists of sandstones, shaly sandstones, fireclays, and coal seams; but there are not many important ironstone seams in this Upper Carboniferous series.

The Central Coalfield, or Lanark Coalfield, is by far the most important of the Scottish coalfields. It extends into the counties of Lanark, Renfrew, Dumbarton, Stirling, Clackmannan, and Linlithgow, and is cut through by the Clyde, in the south-west, and the Forth, in the north-east. The bulk of the coal production is from Lanark, the output of which in 1936 was about two-thirds that of the whole field. Stirling and Linlithgow were the next counties in order of output. The whole coalfield produced over 14,000,000 tons of coal in 1936, or about 44 per cent. of the total output of Scotland. The reserves of coal in this central field are estimated at over 2,600,000,000 tons.

Glasgow is at the western end of the coalfield, and coal-mining is an important industry in the eastern part of the city itself; other important mining centres are Coatbridge, Motherwell, Wishaw, Airdrie, Falkirk, Kilsyth, and Alloa. The famous Splint coal, one of the seams of the Coal Measures series, is three to five feet in thickness, and persists over the greater part of the coalfield; the coal from this seam has been much used for blast-furnaces and steel-works. It is important to remember that more than twice as much coal as coke was used for iron-smelting in Scotland in 1929.

However, it does not follow from this that the Scottish coals will not coke. In the Stirlingshire part of the Central Coalfield there is a good coking coal, and modern by-product ovens and the old beehive ovens are both found there and in other parts of the Scottish Coalfield. In the Central Coalfield some anthracite is obtained, which is largely exported to Canada.

The Central Coalfield contains a good deal of blackband ironstone, especially in the middle group of the Limestone series; and as there is, as is shown by the name, plenty of limestone close at hand there has always been much iron-smelting done in the region. The famous Carron iron-works, in Stirlingshire, were founded in 1759. There are at present nine works on the Central Coalfield for the manufacture of pig-iron.

The Forth Coalfield may be subdivided into two parts, the Fifeshire Coalfield, on the north side of the Firth of Forth, and the Midlothian Coalfield, on the south side. The coal seams in Midlothian are the same generally as in Fifeshire, and the fields are almost certainly continuous under the sea; on both sides of the Firth of Forth some mines are worked under the sea for a short distance from the coast.

The Fifeshire Coalfield is now second in size in Scotland, and extensive developments have taken place on it within the last twenty years. The Limestone coal group is especially rich in good, workable seams in Fifeshire, and it is in these mines that so much development has recently taken place. There is also an area of about twenty square miles where the upper Productive Coal Measures are well developed.

The coal seams in Fifeshire yield house, steam, gas, and manufacturing coal. Some of the steam coals are remarkably good, and that of one of the mines is on the Admiralty list as a steam coal of the first class. Some of the seams have been converted into anthracite in the neighbourhood of the igneous rocks which have been thrust into the Carboniferous strata. There are also excellent parrot or cannel coals, one of which was much worked formerly and is said to have yielded seventy to eighty gallons of oil per ton of coal.

The Midlothian or Edinburgh Coalfield, across the Firth

of Forth, has many of the characteristics of the Fifeshire Coalfield. There are excellent coals in both the Carboniferous Limestone series and in the Productive Coal Measures. Below the Carboniferous Limestone series is the Sandstone group, called here the Calciferous Sandstone series, and it is in these beds that the famous oil-shales of that region are so well developed. The Productive Coal Measures are visible in the east of Midlothian or Edinburgh county; the coals of the Carboniferous Limestone series rise to the surface in East Lothian or Haddington county; the oil-shales of the Calciferous Sandstone series are best seen in West Midlothian and East Linlithgow. Thus, in a general way, from west to east in the Lothians there are available for exploitation first the oil-shales, then the Coal Measures, and then the coals of the Limestone series. Parrot or cannel coal is of widespread occurrence in many seams of the Coal Measures; the seams generally yield house, gas, and steam coals. Adding the resources of the Lothians and Fifeshire together, the total coal in reserve is estimated at about 6,250,000,000 tons. The output in 1936 was: Fifeshire 8,300,000 tons, Edinburgh about 3,700,000 tons, Haddington 1,106,000 tons. At the present rate of output the coal will probably last 500 years.

The Ayrshire Coalfield follows next in size after the Central Coalfield. This coalfield extends from the southern limits of Renfrew county for twenty-five miles, and has a maximum width of fourteen miles. There is a big patch of igneous rocks in the middle of the coalfield, and many minor igneous intrusions have been thrust into the coal-beds, and much coal has thus been destroyed. The available resources, in good condition, are estimated at over 1,000,000,000 tons; the output in 1936 was 4,427,000 tons. On the western side the coal-bearing strata pass under the sea, but it is not easy to estimate the amount of coal which may be obtainable within working distance of the actual shore-line. Most of the coal is of the bituminous type, and the seams provide household and manufacturing coals; gas-making coals also are common, and cannels were extensively mined up to the time when the incandescent mantle gave the deathblow to the importance of cannel for gas-making purposes. There are

local occurrences of good steam coals, and near Kilmarnock one seam has become an anthracite coal. In some limited areas the same coal seam has been subjected to great heat from igneous intrusions, and has been so far burnt that it has been rendered worthless.

There are three areas in the South of Scotland, outside the three main coalfields just described, where coal is now worked. The Douglas Coalfield lies to the south of the Lanark Coalfield, in the valley of the river Douglas, a tributary of the river Clyde. It occupies an area of thirty-five square miles, and is comparable in importance with some of the small coalfields in West Central England. The Nine Feet or Splint coal (which is present in each of the three major coalfields) is again important; other good seams are called the Six Feet and the Four Feet respectively.

A small coalfield at Sanquhar, in the upper valley of the Nith, contains the Productive Coal Measures, but not the Carboniferous Limestone series. The coal-bearing strata occupy a hollow in the Lower Palæozoic rocks of the southern uplands. The Splint seam is again important. The main line of the former Glasgow and South Western Railway, now one of the main lines of the London, Midland, and Scottish, passes through this small coalfield. There are concealed coal-bearing beds near Annan, in Dumfriesshire, lying under Permian and Triassic rocks, and it is suggested that these may be continuous with the concealed coal-beds in the Carlisle basin.

The total output of coal from all the Scottish coalfields amounted to 32,000,000 tons in 1936; this was about 2,000,000 tons less than that of the South Wales coalfields in the same year. Summarizing the position again, the order of output of that fairly normal year was:

	Million tons
(1) Yorkshire, Derbyshire and Nottinghamshire Coalfield	73·9
(2) Northumberland and Durham Coalfield	48·6
(3) South Wales and Monmouthshire Coalfield	35·7
(4) Scotland	32·0
(5) Lancashire and Cheshire Coalfield	14·9

These were the regions which produced over 10,000,000 tons each in 1936. It will be noticed that Scotland is taken as a whole. If the Central Coalfield is considered separately the output for that coalfield is about half a million tons less than that from the Lancashire and Cheshire Coalfield. The reader will notice that the five districts enumerated account for over 87 per cent. of the total coal output of Great Britain.

CHAPTER VI

THE COALFIELDS OF IRELAND

VISIBLE Coal Measures cover but a limited area in Ireland. The Carboniferous Limestone occupies about two-thirds of the whole island, and in many places it is overlain by patches of Millstone Grit. This formation appears on the geological map as outliers here and there, some of them in their turn being surmounted by outliers of Coal Measures, but on several of them this Upper Carboniferous formation is totally wanting.

It is thus quite probable that about two-thirds of Ireland was once covered by Coal Measures, but in the long course of denudation in the Mesozoic and Tertiary eras most of the Coal Measures and a good deal of the Millstone Grit were removed by rain and rivers; and the process was carried still farther in the Great Ice Age.

The patches of Coal Measures still remaining occur scattered over various parts of the island, from near Fair Head, in the north-east, to County Kerry, in the south-west.

Coal in Northern Ireland. A small patch of coal is seen in the coast section at Ballycastle Bay, west of Fair Head, in North-east Antrim. This seems to be a continuation south-westward of the Coal Measures of the Scottish Lowlands, and the beds occur in the Carboniferous Limestone series as they do in parts of Scotland. The exposed coal seams are of little economic importance, but some day a wider extent of them may possibly be proved by borings through the volcanic rocks of Antrim, under which they seem to pass westward. Six seams of coal have been noticed in the sections of Murlough Bay, in this district, four of them bituminous and two anthracitic. When the writer visited the little 'coalfield' some few years ago two or three men only were working the coal, by means of adits from the cliff-face.

The Ballycastle seams must have been more extensively

worked as far back as the seventeenth century, for in 1770 some miners, in pushing an adit inward toward a seam of coal in an unexplored part of the small coalfield, found a passage which had been carried several hundred yards and then

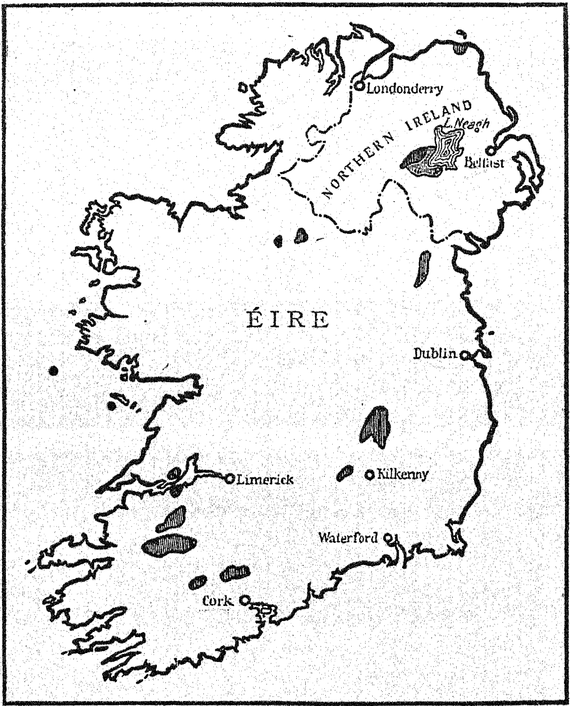


FIG. 9. THE SCATTERED COALFIELDS OF IRELAND

branched off into mining chambers; this had been made by an earlier generation of miners, and all knowledge of it seems to have been forgotten.

A much more important coalfield exists in County Tyrone, near the south-western end of Lough Neagh. The coalfield is small even compared with those of the South and West of Ireland, but in the thickness and quality of its coal seams it is superior. Eight coal seams have been known for sixty

years or more, ever since the descriptions of Griffith, but in quite recent years a bore proved the existence of twelve seams of coal, some of which are said to be of good quality. The best-known seam is the Annagher coal, which is nine feet thick. There are two small patches of coalfield in that district, the Coalisland field, close to the south-western corner of Lough Neagh, and the smaller Annaghone field, not far away.

The commission appointed by the Government of Northern Ireland in 1923 to inquire into the mineral resources of that province reported that the proved and visible coalfields of Northern Ireland contained over 60,000,000 tons of coal. The exploitation is yet in its infancy, however.

The Coalfields of Ireland (*Éire*).[1] In addition to small patches of Coal Measures in Leitrim, Cavan, Monaghan, and Meath, there are coalfields of greater importance in other parts of Leinster and Munster. The more important one, that of Leinster, is in the counties of Leix,[2] Kilkenny, and Tipperary. The coalfield is in the form of a basin, and coal-bearing beds of the Lower and Middle Coal Measures lie on shales, flagstones, and limestones of the Millstone Grit and Carboniferous Limestone series. Bituminous and anthracitic coals are obtained.

In Munster the coalfield consists of a number of patches in the counties of Clare, Kerry, and Cork. Where the three counties of Kerry, Limerick, and Cork meet is the largest visible coalfield. The Coal Measures are usually dipping at a high angle, and are much disturbed; they seem to belong to regions affected by the same movements which affected the Armorican coalfields of Great Britain. The beds are much contorted in places, and sometimes the coal seams have been so much compressed as to be in one place only a few inches thick, while in other places they expand into coal-pockets of twenty to thirty feet in thickness. This disturbed character is more manifest in the south than in the north of the region; in Northern Limerick and Clare the beds are less disturbed.

The figures for the output of coal in the island for the last

[1] Formerly the Irish Free State. [2] Formerly Queen's County.

few years are not easily obtainable. There is no doubt whatever that it is small. Coal-mining is in the exploitation or experimental stage in Northern Ireland. In Éire there were about 78,000 tons of coal mined in 1929, since when statistics are not available. In 1936 about 2,500,000 tons of coal were imported entirely from Great Britain.

CHAPTER VII

DIRECT USES OF COAL

THERE is still much to be done to coal after it has been hewn from the seam and brought up the mine-shaft. The coal-getters are expected to see that as little waste as possible is loaded into the trucks which take the coal to the bottom of the shaft, and after that there is the picking, grading, and washing, which is usually done above-ground. Some grades of coal are picked by hand, the smaller kinds are separated by various kinds of screens, jiggers, etc., and some kinds are carefully washed.

The hand-picking is usually done by boys. Long conveyer-belts made of steel travel slowly through the picking-shed; the boys stand at each side of the belts, and as the coal passes them they pick out the pieces of shale or other rock, while the clean coal travels forward, either to separators or to the loading trucks. This process applies particularly to cobbles. Small coal is usually screened by rotating, shaking, or vibrating screens, which have suitable perforations to allow the separation of the different sizes of the small coal. It is not necessary to wash or specially dry-clean all the coal; but it is usual so to treat the coal that the proportion of ash is not too great when the coal is burned. There were in Great Britain in 1936 780 plants for washing and cleaning coal, and about 42 per cent. of the output, or 82,511,000 tons of coal, was thus cleaned. Scotland stood above England and Wales in the proportion of coal which was washed or cleaned. In the case of all these processes any loss must be reduced to the lowest possible limit, and even the small dust recoverable from the washings, or slurry, as they are called, now finds a market.

The various ways of using coal may be reviewed and restated briefly again at this point:

(1) It may be burned in the natural condition (after sorting

and washing) to produce heat for domestic or industrial purposes. The first and most obvious industrial use is to raise steam, which in its turn is used for heating or for the generation of mechanical power. The power thus generated may be used directly for locomotion or for manufactures, or it may be converted into electricity, which can be stored and used as required for the production of heat, light, and power. The use of electricity generated by steam through the means of mechanical power is extending rapidly at the present time.

(2) The chief constituent of coal is carbon, and some of it is used directly in certain chemical operations where the carbon is required as a reducing agent. Some blast-furnaces, especially in certain districts, use coal and not coke, though the great majority use the latter. In 1936 the amount of coal used in blast-furnaces was somewhat over 83,000 tons; the amount of coke made was well over 8,000,000 tons, or nearly a hundred times as much. The Scottish coalfields are the chief regions in which coal is used largely in the blast-furnace, and the amount of coal used in the Scottish blast-furnaces was to the coke in the proportion of 7 to 3. The furnaces of Lincolnshire, the North-east, and the North-west used only coke. There are certain other chemical operations in industrial chemistry in which finely powdered coal is used, one example of which is the reduction of barytes, or barium sulphate, to the sulphide, in the manufacture of barium chloride; but the further consideration of such processes belongs more to a technical treatise than to the present volume.

(3) A third way of using coal is to carbonize it—that is, to submit it to the process of dry distillation in a retort. This is the basis of a group of industries which are now developing very rapidly, and from new processes of which great things are expected in the immediate future. For the sake of convenience the carbonization processes may be divided into three groups, according to the type of coal used, the temperatures employed, and the products sought to be obtained: (*a*) *The coal-gas manufacture.* Here gas is the main product, and coke, coal-tar, and ammonia are the chief by-products. (*b*) *The coke-oven industry.* Here coke for blast-furnaces, steel-

making furnaces, foundry work, and metallurgical processes is the main product, and gas, ammonia, and tar are regarded as by-products. (*c*) *The low-temperature carbonization processes*, in which semi-coke or other smokeless, readily combustible fuel is the main product, and gas, tar, tar oils, and ammonia are the by-products.

The Coal-gas Manufacture. This is carried on everywhere; and roughly 17,760,000 tons of coal were used in the process in 1936. One may see, or sometimes recognize by the smell, the little gas-works of the small country town on the one hand, or on the other the vast concerns which supply London or the great provincial cities. The big works, in or near the centres of vast populations, are little evident by their smell, but are known rather by the tremendous gas-holders or 'gasometers.'

The actual processes of coal-gas manufacture concern the technologist; an elementary statement of the simpler principles will be sufficient here. Coal of the right kind is heated in retorts, in absence of air, and the volatile products are led off through a series of pipes and scrubbers. In the washing or scrubbing of the issuing gas there are obtained ammonia, usually some sulphur, and the dark-coloured liquid known as coal-tar. The washed and purified gas passes on to the gas-mains or to the gas-holder. At the end of the operation, or at intervals in the continuous processes of coal-gas manufacture, coke is recovered from the retorts and is then cleaned, to be sold largely for domestic uses. A table of the process and the products is as follows:

Coal heated in a coal-gas retort	Coal-gas	
	By-products	Coal-tar
		Ammonia
		Sulphur
	Gas Coke	

The manufacture of coal-gas and its storage and its use in the home and in industry have now reached a very high

stage of efficiency. Before the Great War the normal efficiency of a successful gas-plant was round about 70 per cent. —that is, of the theoretical energy present in the coal used in the gas-works approximately 70 per cent. was realizable by a proper way of using the gas in the home or in industry. To-day many gas engineers claim to have reached an efficiency of 85 per cent. to 90 per cent. New methods of production of coal-gas and the mixing of water-gas with coal-gas in the works have made for great economy in both labour and space.

Coal-gas manufacture is a high-temperature process of carbonization, the temperatures used being generally between 900° C. and 1000° C. There may be considerable rivalry in the near future between high-temperature carbonization (about 900° C. or above) and the newest low-temperature carbonization process (about 600° C. or below). The coal-gas industry is, however, well established already, and about £170,000,000 capital has been sunk in its development. Such an advantage will not be overcome easily.

Gas coke is usually sold locally, but a certain amount is exported; the locally sold supplies are used in the home in the 'greenhouse,' in schools, colleges, churches, clubs, hotels, and other buildings which have central heating. Over 13,700,000 tons of coke were made in Great Britain in the fairly normal year 1936, and of this over two million tons were exported.

The ammonia from the coal-gas manufacture is converted into ammonium sulphate, and more rarely into ammonium chloride; the ammonium sulphate is a valuable manure. The tar from the smaller gas-works is usually sent to the tar-distiller, whose works are found in most of the more densely peopled districts. Many of the bigger gas-works distil their own coal-tar, and in some cases the primary distillation is followed by other separation processes. Some of the products of the ultimate distillation will be mentioned later in the chapters on chemical manufactures.

The coke-oven industry is not so widespread as the coal-gas manufacture, because it must have regard to the location of the metallurgical industry, which is the only market for the

main product. Furnace coke is made from coal, and is used in the iron or steel furnace and in the forge or foundry. The question sometimes arises, Shall the coke ovens be erected on the coalfield or nearer the sources of the iron, where the furnaces are often situated? There is no absolute rule; in

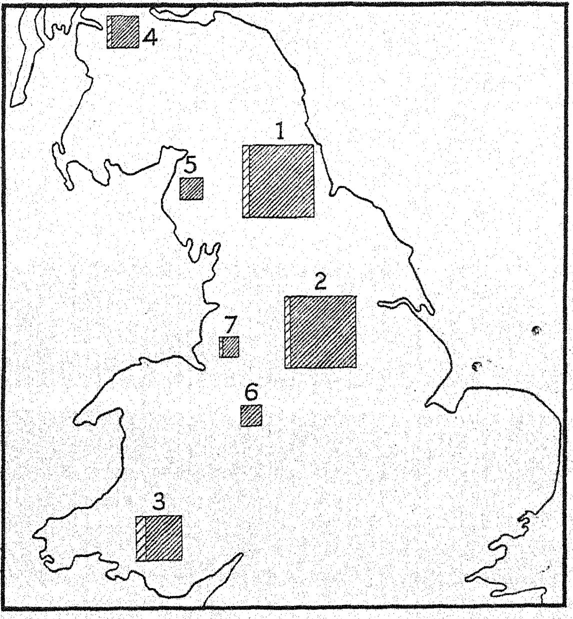


FIG. 10. THE COKE-OVEN INDUSTRY, AS IN 1936

The squares are approximately proportional to the number of ovens, by-product ovens being shown by close shading, other types by open shading. (1) Northumberland, Durham, North Yorkshire; (2) Yorkshire, Derbyshire, etc.; (3) South Wales, Monmouth, Forest of Dean; (4) Scotland; (5) West Cumberland; (6) Staffordshire, Warwickshire, Shropshire; (7) Lancashire, Cheshire, North Wales.

Lincolnshire and the North Riding of Yorkshire the coke ovens are side by side with the iron furnaces and near the sources of iron ore; in many other regions they are close to the coal-pits.

There are coke ovens on nearly all the coalfields, but some regions are far more important than others. In 1936 there were 7044 coke ovens working on an average during the

year in Great Britain; of these 35 per cent. were on the South-east Pennine Coalfield and in the adjacent part of Lincolnshire, where the Jurassic iron ore is worked, and $36\frac{1}{4}$ per cent. were on the North-eastern Coalfield and the adjacent part of the North Riding. These were the leading regions, and in them over 73 per cent. of the coke of Great Britain was produced. South Wales, Monmouthshire, and the Forest of Dean together contained over 14 per cent. of the British coke ovens, and produced slightly over 12 per cent. of the coke. Lancashire, Cheshire, and North Wales had $2\frac{1}{3}$ per cent. of the coke ovens, Scotland a little over 6 per cent., Cumberland $3\frac{1}{2}$ per cent., and the Midlands and the Severn region under 3 per cent.

The total amount of coal carbonized in the coke ovens of Great Britain in 1936 was 20,000,000 tons, or more than the amount that was carbonized in coal-gas manufacture; the coke produced was 13,750,000 tons. Of this amount 2,310,000 tons were exported to other countries during that year.

The county of Durham has long enjoyed a high reputation for its excellent furnace coke; the latter is usually hard and firm, and contains little sulphur and phosphorus (those enemies of the ironmaster). This is particularly the case in the south-west of the county. Coke made from the famous Brockwell seam of that region has been very famous, and was in great demand for the smelting of hæmatite-iron ore. Unfortunately this seam is now nearly worked out, but other seams in Durham, Yorkshire, and Derbyshire are now yielding coke almost as good.

When Abraham Darby made his first successful experiments in Coalbrookdale, in the early part of the eighteenth century, and for long after that time, the furnace coke was very often made from big pieces of coal piled in heaps which had a central draught-chimney, much after the fashion of the charcoal-burner's. Now the coal is placed in an 'oven,' or in a retort oven. There are two main types of oven in use; the simplest form is the old-fashioned 'beehive oven,' which has a somewhat hemispherical roof with a circular hole in the top. It burns its own freed gas inside the oven. This type has been in use more or less since the early days of the coke-

making industry, and is not yet totally supplanted. The other general type of oven is the retort oven, which has arrangements for the condensation of the volatile products. This is commonly known as the by-product oven. It is gradually replacing the older beehive type, although the coke from the latter is still preferred for special purposes by some ironmasters.

There has been a very great development in the coke-making industry in Durham, Yorkshire, and Derbyshire during the present century, and most of the big colliery companies in those counties have coking-plants of one of the twelve commoner types of by-product ovens. Some of these plants supply gas for domestic use to the towns and villages in the neighbourhood, and an inquiry is now on foot to investigate the possibility of a closer working connexion between coal-gas works and coke-oven plants.

Some of the great companies may be quoted as illustrations of the range of activities with which coke-making is now linked up. One great firm, which dates back to the eighteenth century, owns collieries, coke ovens, plants for further distillation of the tar and other by-products, and blast-furnaces. Another great firm, which was in existence when Brindley made the Chesterfield and Trent Canal in the eighteenth century, owns big collieries, over two hundred coke ovens of the by-product type, and nine blast-furnaces. This great combination uses both the gas from the coke ovens and the 'waste' gas from the blast-furnaces, and also carries on the chemical operations for extracting some of the more elementary chemical products from the by-products of the coke ovens, and from the 'waste' of the blast-furnaces. As a third illustration, there is one big combine which owns ironstone mines in Northamptonshire and Rutland, collieries in Derbyshire and Nottinghamshire, coke-oven plants of the by-product type, blast-furnaces, foundries, and a forge. The above three examples are from the Yorkshire, Derbyshire, and Nottingham coalfield. To the list may be added a typical one from Durham; this is a great iron company, which owns collieries, has its own by-product coke ovens, makes sulphate of ammonia, crude benzol, solvent naphtha, tars, pitch, and

creosote, owns its own blast-furnaces and makes different grades of pig-iron, has open-hearth steel furnaces and steel-rolling mills and makes bricks and shapes of fireclay, silica, ganister, etc. These examples can be matched from other coalfields, and they show the intimate way in which coal-mining, coke-making, iron-mining, iron-smelting, steel manufacture, and chemical industries are now linked together.

There are some interesting peculiarities about the location of coke manufacture and the transference of suitable coke from one region to another; and as some text-books are not quite clear on the subject a selection of these may be given here by way of illustrating several principles. It is sometimes assumed that the retention of the old beehive oven in certain districts is just an example of British inertia; this is certainly not always the case. Here is an extract from an advertisement of one of the most up-to-date firms in Britain: "We are makers of high-grade Durham Foundry cokes (beehive and patent oven), low in sulphur and ash, and of great mechanical strength." The reader may be quite certain that there is a good technical reason if the foundry-men and other ironmasters prefer the old type of beehive coke for certain kinds of smelting. Lancashire, Cheshire, and North Wales had, on an average, 221 beehive ovens in use in 1936, and 145 by-product ovens; Scotland had 47 beehive ovens and 415 by-product ovens. These wide-awake districts would not use so many beehive ovens unless there was a real demand for the type of coke they produce.

Lord Aberconway, in his book *The Basic Industries of Great Britain*, makes the statement "the Cannock Chase coal does not coke." In the *Handbook for Birmingham, prepared for the 83rd Annual Meeting of the British Association for the Advancement of Science* there is this statement: "Again, coke, rather than coal, is now the smelting fuel, and the coke most suitable for the process comes not from South Staffordshire, but from districts relatively far removed—*e.g.*, Yorkshire." Notwithstanding these disadvantages, there are still a few furnaces in blast in that region, obtaining their ore from North Staffordshire and from the Jurassic belt of rocks to the south-east, and most (not quite all) of their coke from

Yorkshire and Derbyshire. This illustrates one of the modern great changes in the location of industries.

The case of the coke-supplies for the furnaces of the Barrow-in-Furness region is interesting. The local hæmatite-iron ore is quite close at hand, and a good deal is also obtained from Spain. The local Carboniferous Limestone furnishes the flux. The coke comes mostly from Durham, but supplies are also brought from East Lancashire and South Yorkshire. A daily 'coke train' was for many years a feature of the railway traffic from Burnley to Barrow, *via* Skipton and the old Midland line, but it no longer runs regularly. Some coke is now obtainable from the Cumberland Coalfield, where there was an average of 224 by-product furnaces at work in 1936.

One iron-smelting region still uses coal very largely, and that is Scotland; the Scottish blast-furnaces use much more coal than coke. North Staffordshire also uses some coal in its blast-furnaces.

For the two processes which produce coke, and which have been considered up to this point, from 36,000,000 tons to 40,000,000 tons of coal are needed, and about 25,000,000 tons of coke are produced. Most of the coke made in the coke-oven industry is available for sale or for direct use in furnaces; a considerable quantity of that made in the coal-gas manufacture is used for heating the gas retorts, and that available for sale is about 60 per cent. of the amount made in the gas retorts.

A fairly good, average yield of tar is one hundredweight from one ton of coal, or one-twentieth of the weight of the coal used. The amount of coal-tar produced in the two processes is therefore 1,800,000 tons to 2,000,000 tons. In the year 1931 it was actually a little over 1,600,000 tons; the amount for 1927 was about the same; 1926 was the year of the long stoppage. The working up of the tar will be discussed in a later chapter.

At this point it is advisable to pause and revise a little, so that the part which follows may be more fully appreciated. The carbonization of coal has long been the subject of keen investigation, but at no time in the past have so many physicists, chemists, and engineers been at work as are engaged

in research at present. Gas coke and furnace coke are now well known and their properties are well understood, although it is certain that the last word as to their best use has not been said. The ammonia and the tar have fallen into their places in industry. Still, there are some pressing problems awaiting solution; and it is absolutely necessary that most of them should be solved. These problems concern wasteful ways of using coal, the need for British supplies of fuel oils, and the elimination of some unwise practices that still hold in home life and in industry. There is the waste of fuel involved in burning so much coal in the natural condition; and there is a vast amount of small coal left as waste in the mines. Some millions of tons of coal-tar are lost every year, with all the products which could be made from it. Finally there is the very pressing problem of the smoke nuisance awaiting drastic action. The writer has taught and lived in Burnley, taught in Manchester, and lectured for some years in a London college; and he feels himself unable to say which town has the worst atmosphere. They are all bad: the amount of injury to health and the loss of human energy are appalling in all three places. And there are few considerable centres of population and scarcely one industrial region where improvement is not overdue. This leads up to a discussion of some efforts to solve a part of the problem by low-temperature carbonization of coal.

Low-temperature Carbonization. This process, which is still in the experimental stage, aims at providing a new kind of coke, which will kindle readily in an ordinary fire-grate and burn smokelessly and brightly with a normal draught. There are already about a dozen processes or modifications of processes at work, at places as far apart as Erith, in Kent, and Airdrie, in Scotland. Fuel technologists, gas engineers, and coal-tar chemists are all actively at work, employed largely by private firms who are anxious to be first in the field with a solution of the problem which can be made to pay its way; and the Fuel Research Board, as well as the Fuel Research division of the Department of Scientific and Industrial Research, are keenly watching developments as well as experimenting themselves.

The temperatures employed are usually from 550° C. to 600° C.; hence the general name given to the process. The new solid fuels obtained are already known by proprietary names, and collectively as 'semicoke'; they contain a small proportion of volatile hydrocarbons, which gives them the property of lighting readily and burning without a forced draught; but there is not enough volatile matter to make them burn with a smoky flame. The other products of carbonization are coal-tar, fuel oils and motor spirit, combustible gas and ammonia.

There are widely different ideas among experts as to what these new processes can do. When the Fuel and Power Conference met in London in 1928 the well-known paper *The Manchester Guardian Commercial* issued a special supplement, "Britain's Fuel and Power," in which one advertiser claimed that 1,600,000,000 gallons of crude oil and motor spirit could be produced by his particular process of low-temperature carbonization from 75,000,000 tons of coal. In the same issue two experts said that if the 147,000,000 tons of coal now burned 'raw' could be pre-treated by low-temperature carbonization not more than 441,000,000 gallons of fuel oil would be realized. Probably the 'oils' produced are not of the same order of refinement.

By 1936 fifteen low-temperature carbonization plants were actually in use commercially, as compared with thirteen in the previous year. Their output from the 364,000 tons of coal distilled was 287,000 tons of semicoke, 6,340,000 gallons of tar, 2,043,016 cubic feet of gas, and 1,095,799 gallons of crude spirit from gas. In that year the following quantities of products were obtained per ton of coal treated by processes using coal only:

Semicoke	15·8 cwt.
Gas	31·2 therms (variable)
Tar	16·9 gal.
Crude spirit	2·94 gal.

From plants which carbonized a mixture of pulverized coal and oil or tar the yields were as follows:

Semicoke	90 cwt.
Gas	58·7 therms
Motor spirit	4·73 gal.

Four such plants were in operation, as compared with two in 1935 and none in former years.

A somewhat specialized method of low-temperature carbonization is the Babcock system, which has been worked out at Dunston, Newcastle-upon-Tyne. The coal is preheated to a temperature of 120° C., and then the carbonization is done at a temperature of 650–700° C., by means of a mixture of low-pressure steam and combustion products. The rich retort gas distilled from the coal mixes with the distilling gas, the mixture is 'filtered,' and then passes through condensers, to take out the tar. The low-temperature coke is taken from the retorts and at once conveyed into stokers, where it is consumed in water-tube boilers to raise steam in the customary way. The steam is used for driving steam-turbines and generating electricity. There is thus, normally, no semicoke for sale, but tar, fuel oils, and spirit are obtained as in other processes; the semicoke is used immediately it is produced, before it has cooled. This arrangement is said to make for much greater economy in working. It leaves out of immediate consideration the demand for a smokeless fuel in the home.

In 1928 the Fuel Research Board reported: "Low-temperature carbonization of coal can hardly be expected to supply oil of suitable quality in sufficient quantity to make the country independent of imported oils." Unless unexpectedly large discoveries of petroleum should reward companies empowered to drill for oil by the Petroleum Act (1934), Britain's only practical alternative to reliance on imported supplies (93 per cent.) lies in the large-scale conversion of coal into oil by hydrogenation or synthesis. The calendar year 1936 was the first completed by the plant of Imperial Chemical Industries, Ltd., at Billingham for the production of petrol by hydrogenation; about 33⅓ million gallons were produced from 425,000 tons of coal, in addition to quantities of creosote and tar also processed. To secure the country's independence of imported supplies by this method would require much capital, labour, and raw coal; furthermore, the plant would be extremely vulnerable, and in time of war it might be deplored that facilities peculiar to the import of petroleum had fallen into desuetude.

CHAPTER VIII

THE EXPORT OF COAL FROM GREAT BRITAIN

THIS is a subject of great importance in the industrial life of the country. Great Britain has almost ceased to be an exporter of foods and raw materials; coal is the one remarkable exception under the latter head. The value of the coal exported in 1929 (declared value, free on board) was £48,616,811 sterling;[1] this is a considerable item in the nation's revenue, but the sales value is by no means the only important consideration.

The money represents purchasing power abroad, and the export of coal buys for Great Britain much food and necessary raw material for her manufactures.

It should be remembered, too, that Great Britain is the world's greatest carrier; and the more cargo she has to carry outward, the more fully are her ships employed and the more cheaply can imports be brought from other lands to Britain. For example, a merchant steamer carries coal to the Baltic ports and returns laden with timber; it is obvious that if the ship has full cargoes outward and homeward the more cheaply can the carriage be done, and this tends to keep down the price of imported timber. Similarly with a ship which brings raw cotton from Galveston or New Orleans, or wheat or maize from Buenos Aires or Montevideo, or Chile nitrate from a Chilean port, and so on; these ships need outward cargoes as well as homeward cargoes if Britain is to retain her big share of the carrying trade and do it effectively and cheaply.

There is a third consideration. Great Britain has over a million men who have been trained to the coal-mining industry; this is a serious heritage from the successful past. The export of coal in 1929 (excluding foreign bunker shipments) amounted to 60,266,618 tons; in 1913 (the year before the Great War) the export was 73,400,000 tons—that

[1] £29,299,239 in 1936.

is, nearly one and a quarter times as much as in 1929. This goes a long way toward accounting for the difference between the 287,000,000 tons output of the mines in 1913 and the 258,000,000 tons output in 1929. If 29,000,000 tons could have been added to the output of 1929 it would have meant that the volume of employment could have been increased by probably 10–12 per cent.; or that where seven men were working eight men could have been employed. Full and effective employment cheapens production and tends to lower prices; and at the same time there is less demand on the nation's resources for unemployment pay and in other ways. Unfortunately time has proved even 1929 to have been, relatively speaking, a peak year as regards export tonnage. By 1937 the figure had fallen to 43,477,000 tons.

The average annual output for 1933, 1934, 1935, and 1936 was very nearly 220,000,000 tons; the average annual export, including the coal-equivalent of coke and manufactured fuel, was about 55,000,000 tons; the average annual export between 1909 and 1913 was 65,500,000 tons, and in 1912 there was a six weeks' disturbance, which lessened both the year's output and the export by some millions of tons. In 1913, the zenith year of the coal industry, the home consumption was 183,850,000 tons, in 1936 the home consumption was 175,900,000 tons, which is not quite so serious a decline. It is clearly the decline in exports which is the chief cause of the 'slump' in the industry, and the question arises: What is the cause of this serious decline in exports?

The Great War disorganized many things, and the British export of coal inevitably suffered a good deal. There was the positive danger during the intensive submarine campaign of the Germans, and the rise in insurance rates and in freights generally would, in any case, have cut down the volume of exports. Coal is a necessity for nations at war; it is, in a way, a munition of war; and British exports were limited, so as to cut off supplies to the enemy and to conserve for the British and their Allies the supplies of coal necessary for their own needs. During the War, and immediately afterward, export prices soared to undreamed-of figures and, of course, markets were lost, some of them apparently not to

be recovered readily. Perhaps the most lasting effect was the stimulus given to the development of coalfields abroad, and to the use of other forms of power. Particularly noticeable was the sharp increase in coal-mining in Spain, the development of the lignite fields on the Continent, the increased efficiency of coal-burning appliances, the great increase in the use of oil, and the consequent lower demand for bunker coal; to these results must be added the great development of water-power in the Scandinavian countries, in France and in Italy; and across the Atlantic the same process was going on in Newfoundland and Eastern Canada.

To some extent British markets for the export of coal have been lost to competitors; these are Germany and Poland in the markets of Europe; South Africa, Australia, and Japan in the markets of the lands surrounding the Indian Ocean and Far Eastern countries; and the United States of America in the markets of South America. Very recently exports to Spain and Italy have been cut to almost zero, on account of the difficulty of securing payment.

It should not be overlooked that there has been, and still is to some extent, a world-wide depression in trade; especially has this been felt in the European countries, some of whom were Britain's best customers before the War. First of all, the War impoverished all the countries engaged, and some of them (including Great Britain) had an unnatural boom immediately after the cessation of hostilities. The decline through impoverishment and the reaction after the boom have left the nations relatively poorer than before.

The British Coal-exporting Districts

Great Britain has two great advantages as a coal-exporter: some excellent coalfields are on the coast, and others are but a short distance away, and the coal is of a sufficiently varied character, including, as it does, anthracite, steam coal for ships, good manufacturing coal, coking coal, and excellent domestic coal. Long experience has taught British exporters the best way of transferring coal from the colliery to the ship's hold; and their 'colliers,' as the ships that carry coal

especially are named, are probably the best-equipped for their work in the world.

A geographical study of coal exports may well proceed clockwise round the coasts of Great Britain, beginning in the East of Scotland. The coalfields of Fife and Clackmannan,

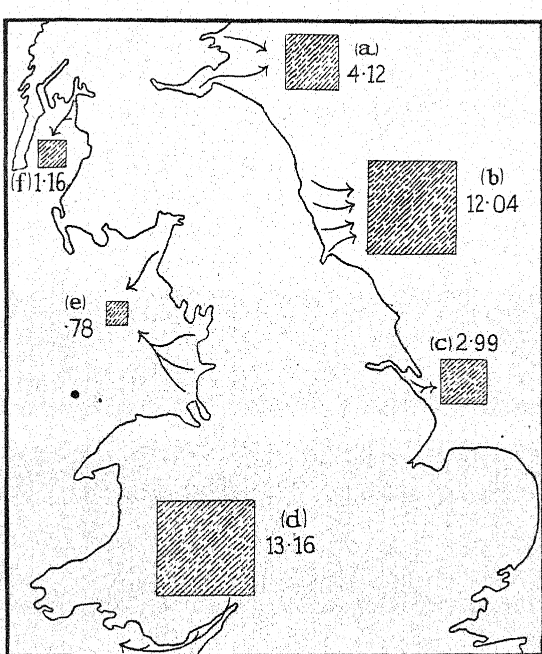


FIG. 11. EXPORT OF COAL FROM THE DIFFERENT AREAS (1936)

(*a*) East of Scotland, from Tay and Forth; (*b*) North-east England; (*c*) Humber ports; (*d*) South Wales, Monmouth, and Gloucester; (*e*) ports of Lancashire, Cheshire, and Cumberland; (*f*) ports of Clyde and Ayr. The figures are millions of tons.

of the Lothians, Southern Stirlingshire, and Lanarkshire are the contributors; the ports from which the coal is sent out are on the east coast of Scotland: Leith, Granton, Bo'ness, Grangemouth, Alloa, Burntisland, Kirkcaldy, and Methil. About 92·5 per cent. of the coal from these ports goes to the countries round the North Sea and the Baltic.

The second exporting coalfield is the one which stretches

from the river Coquet to the river Tees, and which is often referred to as the Newcastle Coalfield, because that city is almost in the very middle of it. In respect of quantity exported, this coalfield is second, but in respect of its long history in connexion with coal exports, it is undoubtedly first. The chief exporting places are Amble and Blyth, on the Northumberland coast, North Shields and South Shields, at the mouth of the Tyne, Newcastle, and the Tyne itself. The last-named includes the coal-shipping staiths belonging to the Tyne Improvement Commission and the London and North Eastern Railway at Whitehill Point, Albert Edward Dock, Northumberland Dock, Tyne Dock, Dunston, West Dunston, and seventeen private staiths belonging to the colliery companies. Other coal ports for this coalfield are Sunderland, Seaham, and Hartlepool, on the Wear and the Durham coast, and Port Clarence, West Stockton, and Middlesbrough, at the mouth of the Tees.

Amble, Blyth, and Seaham Harbour have grown up almost exclusively as ports for the export of coal. Blyth, at the mouth of the little river Blyth, was largely made by the old North Eastern Railway, now a part of the London and North Eastern system. The river was deepened, and special staiths were built, so that railway-truck loads could be tipped directly into the holds of the special iron-built colliers which are such a feature of that coast. The coal is largely brought from the Ashington Coal Company's four collieries at Ashington, Linton, Woodburn, and Ellington. The coal shipped at Blyth consists mainly of hard steam coal and of pulverized coal for steam production on ships

The history of the shipment of coal from the Tyne is almost a romance of industry. It is believed that coal was shipped by the monks of Tynemouth Priory as far back as 1269. 'Sea-coal' was certainly known in London in the fourteenth century and for many a century afterward. In the later Middle Ages sea-coal was brought from the Tyne and up the river Thames to the Fleet, and was sold in the adjoining Seacoal Lane.

One can picture the growing trade as it was carried on in the very early days of the Industrial Revolution. Deep

mining was almost unknown, because of the difficulties occasioned by water; these were not really overcome until Boulton and Watt's steam-engines replaced the imperfect ones of Newcomen and others. Hence much of the mining was of the 'outcrop' type, or at adits on a hillside, often connected with a comparatively short shaft not far away. Those collieries which depended upon export were situated not far from the Tyne and the Wear; and from the pits the coal was carried by pack-horses to the keels on the river; somewhat later came the common use of horse-drawn trucks on rails. Newcastle keels were flat-bottomed boats which carried coal from the riverside lands to the old wooden-walled colliers of those days. The keelmen of the river in course of time claimed special rights and privileges, and there was much wrangling between them and the builders of the coal staiths of modern times. The old sturdy wooden colliers that pursued their leisurely way from the Tyne to the Thames were a great and famous feature of those early days of industrial developments.

In the middle of the nineteenth century iron began to take the place of wood in the building of colliers, and now there is a regular fleet of well-equipped, high-powered ships of 3000 to 4000 tons, with wireless and all other modern, up-to-date appliances. These modern colliers carry coal to the Thames, to the North Sea ports, to the Baltic, the Mediterranean, and to the rest of the world in a less degree. With the growth of economic nationalism, however, the importance of the seaboard location which gave impetus to the rise of these coal ports in connexion with the development of the industrial north-east has declined, and the figures of their exports have very much fallen.

The third exporting region in this review round the coasts is the Humber, where the four ports Hull, Goole, Immingham, and Grimsby are all well equipped for the shipment of coal.

This third region has had difficulties as an exporter of coal. Probably the great rise in railway charges has cut out a large amount of the trade. Of course, there is no coal-pit contiguous to the ports, and, excepting in the case of Goole,

there is a considerable journey by rail or by canal and river from the pit to the port. In 1913 these ports exported nearly 9,000,000 tons of coal. The amount, however, went down in 1924, 1925, and 1927, though in 1929 it stood at near 9,000,000 tons again, excluding the coal taken for the use of steamers engaged in the foreign trade. By 1936, however, it had fallen to 3,000,000 tons. The leading regions to which the coal was shipped were the North Sea and the Baltic ports, as may be expected. Polish coal had, however, become a competitor in the Baltic.

The fourth great region of coal exports is the Bristol Channel, chiefly, of course, the South Wales ports, because the Forest of Dean Coalfield, the Bristol Coalfield, and the Somersetshire fields are only small coalfields. The chief coal-shipping ports in this region are Llanelly, Swansea, Neath, Briton Ferry, Port Talbot, Barry, Penarth, Cardiff, Newport, and, in a much smaller degree, Avonmouth and Bristol. Barry is especially equipped for the quick loading of coal for export, twenty-ton coal wagons being dealt with rapidly and easily. A coal vessel carrying over 4000 tons of coal can be loaded in about six hours, or at the rate of 650–670 tons per hour. Barry holds the record for coal shipment—11,000,000 tons in one year, in 1913. Cardiff is also well equipped to deal with large exports of coal rapidly; the docks are furnished with forty-nine coal hoists and coaling-cranes, and plenty of weigh-bridges are available to register the coal which is being shipped.

The result is that the Bristol Channel region is first in exports of coal in Great Britain, and a bigger share of its coal is sent to almost all parts of the world. The Baltic receives a far less amount of Welsh coal than of coal from the north-eastern coal ports; but the Welsh ports are first in the Western Mediterranean, easily first in the Eastern Mediterranean, and far and away first in exports to the Americas, Africa, and in the small exports to the East.

Some of the reasons for the leading position of the Welsh coalfield in exports may be given: (i) the position is convenient for shipping to every part of the world except the Baltic and the North Sea, and especially convenient for

export to places through or across the Atlantic; (ii) the valleys of the coalfield region run almost north to south, and the natural gradients are toward the ports; this makes it easy to run coal from the pits to the ports; (iii) South Wales can offer to the world different kinds of coal—good bituminous from the eastern part, semi-bituminous steam coal from the middle, and anthracite from the west mainly; (iv) South Wales coal has won for itself a great reputation, and it is in demand more or less all the world over; (v) Welsh coal is in great and continual demand for bunkering purposes, and to meet this demand many of the great hoists can take a twenty-ton wagon, lift it to a height of over seventy feet, and tip its load into the ship; (vi) Llanelly, Swansea, Neath, and Port Talbot are actually on the coalfield, and the other ports are often within not more than six to ten miles of the pits which they serve.

The next region of coal exporting is the North-west, the coal coming from the North Wales, Lancashire, and Cumberland coalfields, or, in rare cases, from across the Pennines or across the Cheshire Plain, from the North Staffordshire Coalfield; the latter cases involve considerable railway journeys, however. The chief ports sending out coal are Runcorn, Manchester, Liverpool, Preston, Fleetwood, Whitehaven, Workington, and Maryport.

The amount of coal exported in the ordinary sense is much smaller than that from any of the other regions, and rarely reaches a total of one million tons a year, which is far less than the export of many a single port of the other fields. The amount of coal for foreign bunkers is, however, fairly high, about as high, for example, as for the whole of Scotland. Ships carry bunker coal as an outward cargo and come back to Great Britain, often to the Mersey or Manchester, with cargoes of raw materials or foods. With regard to the quantity of coal shipped for the use of steamers engaged in the foreign trade, the north-western ports (of the Mersey and the Ship Canal) come fourth in order—that is, after the Bristol Channel ports, which are first, the ports of the Humber, which are second, and those of the north-east.

The last of the great exporting regions or groups of ports

is in the West of Scotland, and includes Ayr, Troon, Ardrossan, Greenock, and Glasgow. The amount of coal exported from these ports is far less than that from the eastern ports of Central Scotland, but the foreign bunker coal is about the same in quantity. On the whole, this region comes fifth in export.

The Customers who buy British Coal

It is now necessary to see what becomes of the coal which Britain exports, and also to inquire where the decline mentioned earlier has taken place. Comparisons between 1911, 1912, and 1913 on the one hand, and 1934, 1935, and 1936 on the other, would appear to be fair and appropriate. The War years and the early years of recovery are omitted for obvious reasons, and 1926 and subsequent years are useless, because of the long national coal stoppage of that year and its deferred effects.

Britain's best customers are near home, and of these France stands easily first. She has been first in every normal year from 1910 to 1936. The serious thing, however, is the steady decline in exports to France since 1923; the drop from 1924 to 1928 was about 38 per cent., 14,500,000 tons having dropped to 9,000,000 tons. From 1927–29 to 1934–36 there has been a further drop of the order of nearly 30 per cent. This expresses a total decline of some 3,250,000 tons per year from the pre-War average.

Britain's next best customer before 1936 was Italy, and here the drop is more serious. That country took a steady 9,000,000 tons in the pre-War years; now the import from Great Britain is 60,000 tons. This low figure may be an isolated instance, due in part to Italy's preoccupation with the Abyssinian war, and the average for 1933 to 1935, 4,200,000 tons, may be a more representative figure. But Italy, as is well known, has developed her water-power resources enormously, and Germany has captured much of the former British trade to that country in coal. It is not at all easy to find all the reasons for this serious loss; the very high prices of British coal for export in the years 1919–23 may be one

cause. Even in 1924 the average export price, f.o.b., was 23*s*. 5*d*. per ton, compared with 13*s*. 10*d*. in 1913. Having once lost a market, it is very difficult to recapture it, as is shown by the fact that a drop in the average export price of British coal to 16*s*. 10*d*. in 1929 has not made any very great addition to British exports of coal to Italy.

Germany is Britain's third best customer; and this in spite of the fact that she herself exports coal freely. Her coalfields are, however, in the middle and south of the country, and the northern plain and the ports are far from a coalfield. Germany has developed her own coalfields somewhat, and her lignite beds especially, since the Great War; and she has not only cut out 42 per cent. of her imports of British coal, but has also captured a share of our former market in Italy. British exports to Germany averaged 8,750,000 tons a year in the three pre-War years selected; they now average 2,824,000 tons. This is another serious loss.

There are a number of countries to which Great Britain usually exports from 2,000,000 to 3,000,000 tons; these are the Argentine Republic, Éire (Ireland), Sweden, the Netherlands, Denmark, and Egypt, including the Anglo-Egyptian Sudan. There has been a considerable decline in exports to Spain and Egypt, and a less decline (still serious) to Norway and Brazil. Sweden has been developing the use of hydro-electric power at a great rate, and she now also buys coal freely from Poland and Germany. Egypt has bought some coal from Russia and from Germany, and the amount used has declined, owing partly to the general world depression in trade, and probably in part to the high prices for coal which have long been ruling. Great Britain has been partly cut out of the Argentine by the United States of America; prices soared to an enormous height at the end of the Great War, and the North American exporters were able to undersell the British exporters. The share of the Argentine market thus lost is not being regained easily.

The development of the world's coalfields has been considerable in many regions during and since the Great War. Nigerian coal is offered to British ships on the West African coast; Natal has taken a great deal of the former East

African trade; Australia and New Zealand both produce coal plentifully now; the former now exports considerably and imports very little; and the latter is gradually increasing her share of exports. In 1924 our export of coal to Australia[1] reached the low level of 9234 tons, out of a total consumed of over 11,000,000 tons. The exports from Australia in 1935–36 (on the authority of the official *Year Book* of Australia) were sent to New Zealand, the Philippine Islands, the Dutch East Indies, Malaya, Fiji, and many islands of the Pacific. New Zealand has practically ceased to import any British coal; she imports from and exports to Australia, and also exports to the Pacific Islands, the Western United States, and in 1926 (the year of the great stoppage) even sent some coal to the United Kingdom. This is quoted from the New Zealand official *Year Book.* The irony of sending coal half-way round the world to Great Britain!

In pre-War years Great Britain sent a moderate amount of coal to British India; that export is now very low. Ceylon takes only about one-twelfth what she took in pre-War years. The export to Chile has also gone down to very low figures. It is quite evident that Great Britain may practically write off the lands of the Far East and of the Pacific coasts as buyers of coal in the natural state. It does not follow, however, that they may not become good customers for substances prepared from coal.

Two conclusions seem to be quite clear. First, the price of exported coal must be kept as low as possible, and the freight charges must be kept low also, if the markets at present held are to be retained, and if there is to be some recapture of those markets which seem to be slipping away. Secondly, it will pay Great Britain better to sell the products of the carbonization of coal; but here again there will be the keen competition of the United States and Germany, and the work will need to be done with all the legitimate efficiency and refinements of modern industry.

[1] No separate figure for 1936.

CHAPTER IX

OTHER MINERALS AND ROCKS: QUARRYING AND MINING

IN the annual reports issued by the Secretary for Mines and by his Majesty's Chief Inspector of Mines, and published by his Majesty's Stationery Office, the word 'minerals' is used to connote all the materials obtained from mines and quarries. The geologist does not use the word 'minerals' in quite that comprehensive sense, but rather he makes it denote the constituents which make up rocks as well as the occasional definite substances that occur in rocks in pockets, veins, and sometimes in layers. It is convenient here to follow somewhat loosely the reports referred to, and to classify everything as 'mineral' which is obtained from the ground by either mining or quarrying. There is no hard and fast boundary between these two processes, although *mining* usually means obtaining rocks or minerals or other useful substances from below the surface, while the term *quarrying* is often broadly used for those operations which are carried on at the surface.

Coal is so extraordinarily important that it completely dwarfs all the other minerals in the British Isles; hence its fuller treatment in the preceding chapters. In this chapter the remaining important rocks and minerals will be considered, including those which are quarried and those which are mined.

The sedimentary and stratified rocks will be considered first, and a natural classification of the rocks will be followed, dealing with them according to their mineral composition: arenaceous rocks, argillaceous rocks, calcareous rocks, and carbonaceous rocks.

ARENACEOUS ROCKS OF INDUSTRIAL IMPORTANCE

Arena is Latin for sand, so that this is the group of sandy rocks—the sandstones and their cognate types. Sandstones

and grits are, perhaps, the most widely used of all building stones. A grit is a coarse sandstone composed mainly of angular grains of its constituent minerals. Sandstones are found in many districts; usually they are not difficult to quarry. They are comparatively easy to work, and they are generally durable. Sandstones from many geological systems and from many geographical regions are well known. The Old Red Sandstone rocks have long been famous; some well-known examples are from the Malvern Hills and from many parts of Herefordshire. They are quarried at Cradley and other places. Tintern Abbey and Chepstow Castle are examples of famous buildings built of these sandstones. Sandstones of similar age are quarried in many parts of Scotland; the flagstones of Caithness and the more massive building stones of Cromarty may be mentioned as examples.

The sandstones and grits of the Carboniferous system, mainly from the Millstone Grit and the Coal Measures, are very largely quarried for building purposes. The Pennant grit of South Wales and the Forest of Dean has been widely used, and quarries are very numerous in the Southern Pennines, from Mow Cop, in Staffordshire, to the Pendle range, in East Lancashire. The Craigleith sandstone, near Edinburgh, is of Carboniferous age.

The sandstones of the Permian and Trias are conveniently grouped together under the title of New Red Sandstone. These yield excellent building stones, rather soft, easily quarried and worked, but fairly durable. Mansfield, Runcorn, Liverpool, Penrith, and Dumfries are all well-known localities. There are few sandstones of age newer than the Trias used for building purposes in the British Isles.

Two English counties stand out beyond all others for the amount of sandstone quarried. Yorkshire comes first, with numerous quarries in the Colne Valley, and at Brighouse, Halifax, Queensbury, Bramley, Saltaire, Bingley, Keighley, and other places. Lancashire is second, and has well-known quarries at Rochdale, Bacup, Rawtenstall, Burnley, Whalley, Nelson, and Colne. Other English counties of the second rank are Warwickshire, Derbyshire, Cheshire, and Devonshire. Glamorgan, in Wales, takes the same rank as the four

English counties just named. In Scotland the leading counties are Lanark, Dumfries, and Ross and Cromarty. The Red Sandstones of Dumfries make very effective building stones, and that town has a very picturesque appearance due to the setting of these sandstones in the green of the fertile valley of the Nith and the grey of the surrounding moors. Shropshire (Salop) is not equal in rank to many other English counties, but it contains the well-known sandstone and flagstone quarries of Ludlow, in the extreme south of the county.

Argillaceous Rocks of Industrial Importance: the Clay-Shale-Slate Group

Ordinary clay is a very widespread rock, of somewhat peculiar properties; one of its chief qualities is its plasticity, which allows it to be moulded into different shapes—bricks, tiles, drain-pipes, and various forms of sanitary ware—the moulded shapes then being baked or 'burnt' in special ovens, or kilns. The common fissile rock, *shale*, has the same general composition as clay, and is put to the same industrial uses, after being finely ground along with water. The shales of the Upper Millstone Grit and Coal Measures are very widely used in many of the coalfields. Clays from various geological systems are also dug and used: the Jurassic clays—*e.g.*, the Oxford clay and the Kimmeridge clay—the Cretaceous clays, such as the Wealden clay and the Gault clay, and the very famous London clay of the Eocene.

The leading counties for the digging or quarrying of clay are Bedford, Lancashire, Yorkshire, and Huntingdon. The Yorkshire yield is mainly from the shales of the Coal Measures and certain Mesozoic clays; the Huntingdon yield is from the Oxford clay, in which formation the large brickyards at Fletton, near Peterborough, are worked; the Lancashire yield is chiefly from the shales of the Coal Measures, these shales being ground up, moulded, and baked into bricks, tiles, and many forms of stoneware at Accrington, Burnley, Nelson, St Helens, Wigan, Horwich, Bolton, Rochdale, and round about Manchester. Counties of the second rank are numerous, and include Staffordshire, Buckingham, Warwick-

shire, Cambridgeshire, Kent, Durham, Derbyshire, and Leicestershire. Glamorgan is the first of the Welsh counties, but is behind the above-named English counties in output. Fife, Lanark, and Edinburgh are the leading Scottish counties, but are in turn behind Glamorgan in output.

A very special clay is *fireclay*. This is a silicate of alumina, as are most other clays, but it differs from them in that it contains very little of the alkalis, potash and soda. It therefore forms bricks, crucibles, etc., which are not readily fusible; hence the name, fireclay. This particular type of clay is often found under a coal seam, to which it forms the floor or seat. On this account one may expect to find it most commonly in the coalfields. This is the case, and the digging of fireclay and the making of firebricks and other forms of fireproof earthenware is often one of the sources of profit of a colliery company. The leading counties, in order of output, are Staffordshire, Yorkshire, Stirling, Durham, Lanark, Derby, Lancashire, and Northumberland. Ayrshire falls behind these counties (except Northumberland) in quantity of output, but in its coalfield there is found an especially excellent and renowned fireclay.

Another special clay is *kaolin*, or *China clay*, formed naturally by the decomposition of the grey and white felspar of granites of Cornwall and Devon. This clay is shipped from Fowey, Par, Charlestown, etc., to the Mersey, to be taken to the Potteries, and to various parts of Lancashire, where it finds an additional use in the cotton industry, and to Kent, Hertfordshire, Lancashire, and other districts, to be used as a filling in paper manufacture. See the section on earthenware, chinaware, and pottery at the end of Chapter XVI.

Slate. This is also a member of the argillaceous group of sedimentary or stratified rocks. It is fairly hard, and through extreme pressure it has been so altered that it will cleave in directions which are independent of the original bedding planes. It has a new and a negative property, in that it cannot be treated as shale can—*i.e.*, ground down with water to make a paste similar to a clay. Slate is largely used for roofing buildings, and for other purposes where relatively thin sheets of rock are required. Real slate is not obtained

from any system of rocks in the British Isles newer than the Carboniferous system, and the very best slates are usually

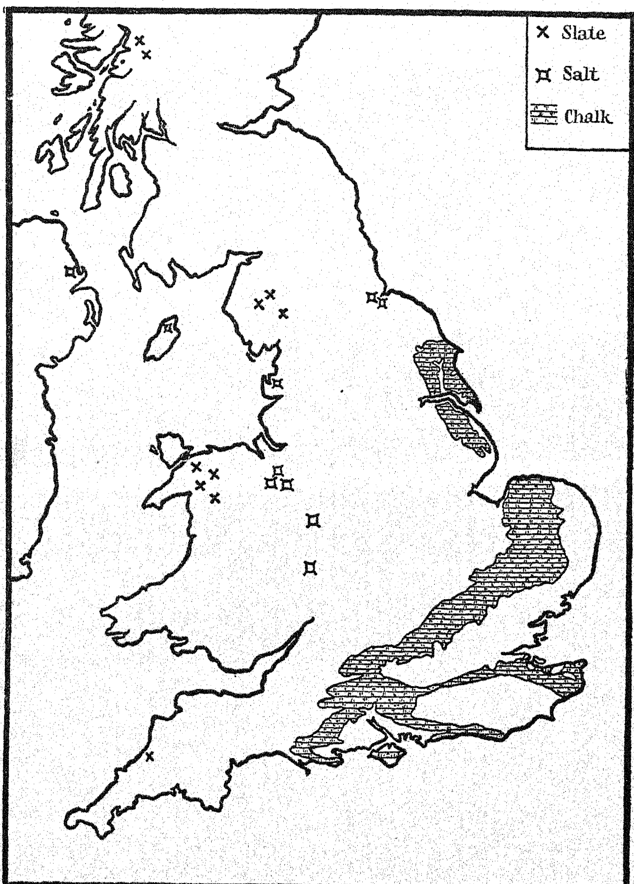


FIG. 12. THE CHIEF LOCALITIES FOR SLATE, SALT, AND CHALK (FOR CEMENT MANUFACTURE)

found in the Cambrian and Ordovician systems, and among the mountains.

Slate has a strictly limited distribution in the British Isles.

More is obtained from Carnarvonshire than from all the other counties added together; in that county are the famous quarries of Penrhyn and Llanberis. Other counties which yield good slate are Merioneth (the famous quarries at Festiniog), Cornwall (the Delabole quarries), Lancashire, Argyll, Denbigh, Westmorland, and Cumberland. Certain fissile rocks, such as sandstones, have been employed for roofing in the past, but these are really fissile flagstones, and should not be called slates. The so-called 'slates' of Stonesfield, in Oxfordshire, and of Collyweston, in Northamptonshire, are examples.

The Calcareous Group of Sedimentary or Stratified Rocks

Limestones. Many of the geological systems contain massive limestones, and most of these have been quarried for industrial purposes. In the Jurassic system there are many thick beds of comparatively soft oolitic limestone, so easily cut and worked in almost any direction as to be called 'freestone.' Some well-known localities are Portland, Bath, Painswick, in the Cotswolds, Corsham, in Wiltshire, Ketton, in Rutland, and Ancaster and Stamford, in Lincolnshire. Some of these limestones are now ground up and used for making the so-called 'artificial stone' for building purposes.

A thick formation of limestone occurs in the Permian system on the east of the Pennines, where it forms a belt extending from the city of Nottingham to South Shields. All the coast of Durham from Hartlepool to the Tyne is formed of this limestone. It has been largely used as a building stone, and has been extensively quarried at Mansfield, Bolsover, and near Doncaster. The Houses of Parliament are built of this stone, as are many castles and country seats in the North-eastern Plain. York Minster is also mainly built of this stone. The limestone, called Magnesian Limestone, is a mixture of calcium and magnesium carbonates, and it is sometimes quarried to make the linings of the iron furnaces in the basic process.

The most widespread massive limestone in the British Isles is the Carboniferous Limestone, a formation which is

sometimes about 3000 feet in thickness. It forms the foundation of most of the great Central Plain of Ireland, and here and there it stands out in fine coastal cliffs, as at Bundoran, for example; it is well developed in the median rift valley of Scotland; from the Cheviots to the Vale of Trent it is more widespread than any other formation, and forms much of the fine scenery of the Yorkshire dales and the equally fine scenery of Buxton, Matlock, and Dovedale, in Derbyshire. There is a rim of this limestone in North Wales, and the fine scarp at Eglwyseg, in the Vale of Llangollen, and the peninsula of Great Orme consist of it. Some of the fine scenery in the lower valley of the Wye is in this limestone, and Clifton Gorge, near Bristol, and the famous Cheddar Cliffs, Gorge, and Caves are other examples.

This limestone has sometimes been used for building, and there are hundreds of miles of stone 'fences' made of it in Derbyshire and West Yorkshire. Its most important use, however, has been for lime-burning, which has been very widely practised. This operation was formerly carried on in small kilns scattered all over the Carboniferous Limestone country; now it is concentrated at Peak Forest, Buxton, Millers Dale, Matlock, Clitheroe, Grassington, Settle, and a few other places.

Enormous quantities of lime are needed for manure, for the making of mortar and cement, in gas manufacture, in the preparation of hides and skins for the tanner, for the softening of water by Clark's process, and for several branches of the chemical industry. One of the most regular important uses is as a flux in the iron-smelting industry; immense amounts of lime or of limestone are demanded for this purpose.

The important limestones which occur in strata older than the Carboniferous are those of South Devon, as at Plymouth and Newton Abbot, which are of Devonian age; and the Wenlock Limestone, in the Upper Silurian system. There is a long, narrow ridge of this latter limestone in Shropshire, where it is well seen at Much Wenlock. A very important occurrence of it is in an inlier of Silurian rocks near Dudley, where the famous Wren's Nest has furnished very large

quantities of lime and limestone to the industrial operations of the South Staffordshire and North Worcestershire coalfield.

The counties in each of which more than a million tons of limestone were quarried in 1936 are Derbyshire, Yorkshire, Somerset, and Durham, in the order given. The Carboniferous Limestone occurs in all these counties except Somerset, and the bulk of the enormous output came from that formation; but in Durham and Yorkshire there is some part of it from the Magnesian Limestone, and a less amount in Derbyshire.

Chalk. This is a white, fine-grained rock, with the same general chemical composition as limestone, but its texture and hardness are so different that it is usually classed apart.

A belt of chalk runs across Eastern England from Flamborough Head, in Yorkshire, to the cliffs of Ballard Point, in Dorset; and from the southern part of this belt three arms are sent off from west to east, along the North Downs, the South Downs, and the middle of the Isle of Wight. This rock rises into a series of low hills—the Yorkshire Wolds, Lincolnshire Wolds, East Anglian Heights, Gogmagog Hills, Chiltern Hills, Berkshire Downs, White Horse Hills, Marlborough Downs, the broad expanse of Salisbury Plain (a low plateau), the North Downs, the South Downs, and the low chalk hills of the 'Isle' of Purbeck and the Isle of Wight.

Chalk is quarried in immense quantities for the making of lime and cement, and lime- and cement-works may often be seen where the low chalk hills are cut through by a river or railway, and where means of transport are readily available. When chalk is heated in the lime-kiln carbon dioxide is driven off and fairly pure lime is left. If chalk containing a good deal of clayey matter be calcined in the kiln a cement is formed; usually, however, cement is made by heating together a very well-ground mixture of a calcareous rock and an argillaceous substance. Chalk and clay are the commonest mixtures used in making the common cement which in Britain is usually called Portland cement. This well-known cement is so called because when it is set it somewhat resembles the famous Portland building stone. The latter is a limestone, and if mixed with a suitable clay a Portland

cement could be made from it, but this is obviously possible with any other similar limestone. One of the most famous places for the manufacture of Portland cement is the Medway and the neighbouring district south of the Thames; here the materials used are mixtures of chalk, Medway mud, and the neighbouring Gault clay, from the southern foot of the chalk downs.

Kent is far and away the leading county for the quarrying of chalk, owing to the Medway and Dartford cement manufactures of Portland cement mentioned above. The next counties in order are Essex, Bedford, and Yorkshire. The chief Essex quarries of chalk are at Grays, on the north bank of the Thames, but chalk is also exposed in the north-west of the county, and there some chalk is quarried chiefly for ordinary lime-burning. The Yorkshire quarries are in the East Riding, principally in the vicinity of the Humber. The Bedfordshire chalk quarries are in the south of the county, in the Luton and Dunstable districts, where a part of the northern scarp of the Chiltern Hills falls within Bedfordshire.

Lincolnshire, Cambridgeshire, Surrey, Sussex, and Hampshire all produced some hundreds of thousands of tons of chalk in 1936, and a glance at a geological map will at once show the reader that some considerable part of the chalk formation of England falls within these counties. Wales and Scotland have no true chalk, and there are only the merest patches in the North-east of Ireland, where it is seen in the 'white rocks' of Portrush, of Rathlin Island, and a few other places. It is worked to a considerable extent on Rathlin Island, and the amount quarried there in 1924 was nearly as large as that of many of the English counties named.

The Carbonaceous Group of Rocks

This group includes those rocks and minerals which largely consist of carbonaceous matter, or which give off combustible gases or hydrocarbon oils on heating. The ordinary coals, lignite, peat, oil-shales, and jet are the best-known British types.

Lignite. This soft, earthy, brownish-black substance is of very great importance in some countries. For instance, in Germany the tonnage of lignite dug per annum is roughly equal to the tonnage of true coal mined; in 1936 the output of coal was 158,282,000 tons, and that of lignite 161,400,000 tons. The British Isles possess, however, very little lignite. Thin, irregular patches and pockets occur here and there in the Eocene beds of South-eastern England, and 'leaf-beds' are found in the Tertiary volcanic series of Western Scotland. The only British examples of lignite of any considerable extent are at Bovey Tracey and Chudleigh, near Newton Abbot, in Devon. The lignites in these districts contain up to 66 per cent. of carbon, but a large percentage of iron pyrites causes this fuel to give out a very disagreeable smell when burnt.

Peat. This is very widespread in the British Isles. It consists of an accumulation of semi-decayed mosses, rushes, heather, grasses, and other plants, and has usually been formed either on the upland moors or in low-lying marshes and fens. It is often brown in colour near the surface, but deeper down it is usually more compact and blackish, and the plants are much more decomposed.

Peat is dug for fuel somewhat irregularly in many parts of Great Britain and Ireland. On the wide South Pennine moors it is sometimes dug by the local farmers and villagers, dried and stacked, and brought down from the moors as fuel for the winter. The traveller by train between Stoke and Macclesfield may sometimes see immense stacks of peat near the railway, which here passes over one of the old 'mosses' of that region. So also the traveller across Chat Moss, or some of the other 'mosses' west of Manchester, may see peat being cut and stacked. The wide moors of the Northern Pennines and the broad moorlands of the Cheviots and Southern Uplands also furnish a good deal of peat for fuel to the people of the immediate district. In the Highlands of Scotland it is the usual fuel.

The greatest peat region in the British Isles is, however, the central plain of Ireland and some of the lower, broad moorlands of that island. Peat is cut, stacked, and dried

systematically for fuel in these two countries of little coal resources, Northern Ireland and Éire.

Peat is sometimes cut and dried to be used as litter for cattle and horses, and afterward to be spread on light sandy soils as manure. As peat contains a good deal of nitrogen and hydrogen, it gives a fair amount of ammonia along with hydrocarbons, liquid and gaseous, when subjected to destructive distillation, but this process has not been developed to any great extent. Peat is occasionally compressed and burned in the form of briquettes, but this process has not been developed in the British Isles to the extent that it has in North-west Germany and in the Netherlands.

Oil-shales. In the Calciferous Sandstone series of the Lower Carboniferous of the Midland valley of Scotland there occur shales known as bituminous shales, or oil-shales. The richer shales yielded from thirty to forty gallons of oil from a ton of shale by distillation (1875), but the average yield to-day is sixteen to twenty gallons per ton. The shale oil obtained by distillation consists chiefly of paraffins and olefines, and is quite different in chemical composition from the light oils obtained from coal-tar and indirectly from coal; the latter are chiefly of the benzine or aromatic series of hydrocarbons. Thus the shale oils are chiefly valuable for light and fuel, and not as sources of other chemical compounds. A certain amount of ammonium sulphate is also obtained from the distillation.

The modern shale-oil industry in Scotland was commenced at Broxburn, in Linlithgow county, in 1862, and the industry has remained concentrated in that region, together with Midlothian, West Fife, and Ayrshire. The oils, when purified and fractionated, are known as gasolene and naphtha; the solid constituents are various types of paraffins. There are, however, different distillation processes used, and the products vary somewhat. Broadly speaking, they may be reduced to motor spirit, naphtha, Diesel oil, lubricating oils, paraffin scale, and refined paraffin.

Some oil-shales have been worked from the Coal Measures of Staffordshire and Flintshire, but not to any great extent. The Kimmeridge clay of South Dorset has also been worked

for burning oils and solvent oils, but the sulphur impurities render the oils thus obtained very objectionable. Similar clays in Lincolnshire, in the Vale of Market Rasen, are sometimes bituminous, and have yielded a little oil on distillation.

Oil-wells. A little oil can be obtained from most Coal Measures shales, and many attempts have been made from time to time to obtain larger and more systematic quantities. Oil has long been known from Alfreton, in Derbyshire, where an oil-distillation plant at one time yielded 300 gallons per day. Production fell off after fifteen months. In recent years a number of borings have been put down in the hope of finding oil in the Carboniferous rocks of South Yorkshire and North Derbyshire. At Hardstoft some oil was obtained from sandy beds apparently at the junction of the Yoredale series with the Carboniferous limestone. Close upon 3000 tons have been produced, and the plant is still functioning. More recently (1938) a drill near Dalkeith (Midlothian) was made to yield 350 gallons daily of high-quality oil. These quantities are, of course, negligible in comparison with the output of wells overseas; but the hoped-for production of even a few thousand gallons a day would be an important contribution to the welfare of this country.

Igneous Rocks as Building Stones and Ornamental Stones

Some of these rocks are used for the more important buildings not only in the districts in which they are quarried, but also farther afield. Thus the streets, squares, and public buildings of London are a wonderful summary of the igneous rocks of Britain. Granite from Peterhead, Aberdeen, Shap, and Cornwall and Devon are seen almost everywhere; the granites from South-west Scotland, the Mourne Mountains, the Wicklow Hills, and the Channel Islands need to be sought out, but examples are by no means uncommon.

The fine, large crystals of brownish-red felspar in polished granite from Shap, in Westmorland, strike the eye everywhere. The fine and large white felspar crystals in the granites of Cornwall and Devon are almost as common a sight, in the streets of the City of London especially.

Igneous rocks are largely used as paving-stones and as kerb-stones in many cities and on many roads. These are quarried and shaped or broken into suitable pieces by machinery in many districts in the British Isles, but not in the south-east quadrant of England, which possesses no igneous rocks in its solid geology. Igneous rocks are also extensively used for monumental purposes on account of their durability.

The following summary of the activities of certain counties will help the reader to appreciate the importance of the subject. Leicestershire is easily the first county in Great Britain in the production of paving-stones, kerb-stones, cut road-metal, and artificial stone. The Charnwood Forest district and round about it is the chief region, some of the famous quarries being at Mount Sorrel, Markfield, Groby, Enderby, and Stoney Stanton. This part of Leicestershire is the nearest source of such rocks for all the counties of South-eastern England, from the Humber to the Isle of Wight, and hence there is a big demand for its productions.

Other counties producing over half a million tons of these rocks in 1936 were Carnarvon, Cornwall, Lanark, and Northumberland. In Carnarvon are the big quarries along the coast at Penmaenmawr, which supply many of the counties and county boroughs in the Midlands and the North-west of England with road-metal and paving-stones, and here again much artificial stone is now made and exported. Cornwall has numerous and immense granite quarries in many parts, one of the most famous districts being near Penryn, a town of greyish-white granite near Falmouth Harbour, where the stone can be loaded directly into small coasting steamboats. Lanark county has an immense number of scattered exposures of volcanic rocks which are suitable for road-metal, paving-stones, and manufacture of modern artificial stone.

Other counties of the third rank in the matter of output of igneous rocks are Shropshire, Aberdeen, Fife, Ayrshire, Edinburgh, Angus, Derbyshire, and Devon. Aberdeen has large granite quarries, and the city is practically built of its own grey granite.

In Northern Ireland the chief regions are the Mourne

Mountains and the great expanse of volcanic rocks in County Antrim; in Éire (Ireland) the granites of the Wicklow Mountains and the other volcanic rocks of Wicklow and Wexford are capable of supplying very large quantities.

Salt. Common salt, or chloride of sodium, is present in normal sea-water to the extent of about 2·7 per cent. There is rather more than this amount in the water of the Mediterranean Sea, rather less in the water of the North Sea, and very much less in the water of the Baltic Sea. Salt was formerly obtained in Britain by the evaporation of sea-water on many parts of the coast; this process gave a crude, impure salt, called baysalt, from which a moderately pure salt was afterward prepared.

Now the supplies of common salt are obtained from deposits which occur interbedded in Triassic marls in Cheshire, Worcestershire, North Lancashire, Staffordshire, near Middlesbrough, and near Carrickfergus, in Antrim.

In South-east Cheshire, two beds of rock salt eighty to ninety feet thick are found, and are mined in some places; rock salt has also been obtained from some of the other localities named. The supply of salt for domestic and industrial uses is mostly obtained from brine. Two borings are put down through the overlying strata until the salt-beds are reached; one of these is used to run down water (if necessary) and the other to pump up the saturated brine. This saturated solution of impure salts is evaporated, and the precipitated salts are further purified until the required degree of purity for the particular purpose is reached.

From the returns of mines and quarries of Great Britain for the year 1936 one learns that no salt, either in the form of brine or rock salt, was obtained from the rocks in Wales or Scotland; 17,291 tons of rock salt were obtained from Cheshire. In 1924 there were 11,000 tons obtained from near Carrickfergus, in Northern Ireland. The chief county for brine was also Cheshire; there the principal region is in the Northwich-Middlewich district. The second county was Lancashire, where the brine is obtained from the salt deposits near Fleetwood. The third yield of brine came from the deposits which occur on the border of Yorkshire and

Durham, near Middlesbrough and Port Clarence. The fourth yield was from Worcestershire, chiefly near Droitwich. A little was also obtained in Staffordshire, and a very little in the Isle of Man.

The salt deposits of England are the foundation of a great chemical industry, as well as having been instrumental, on account of the bleaching properties of the by-products of salt, in determining the location of the cotton industry. The exports of salt were 280,000 tons in 1936.

Gypsum. This is hydrated sulphate of lime, or $CaSO_4 + 2H_2O$. It occurs chiefly in semi-crystalline forms, as nodules and veins in the Triassic marls of many counties. The counties listed in order of output in 1936 were Durham, Nottinghamshire, Staffordshire, Westmorland, Cumberland, Derbyshire, and Sussex.

When gypsum is carefully heated, or calcined, plaster of Paris is produced, and this substance is widely used in the manufacture of cements. The finer, granular kinds of gypsum are called alabaster, from which many ornaments and the toy marbles of children are made. Alabaster is also much used as 'rockery' in gardens. The United Kingdom produced 1,002,472 tons of gypsum in 1936.

It remains to be added that in 1936 83,000 wage-earners found employment in quarrying and mining the rocks and minerals mentioned in this chapter with a few other similar quarry products.

CHAPTER X

IRON AND STEEL IN BRITAIN

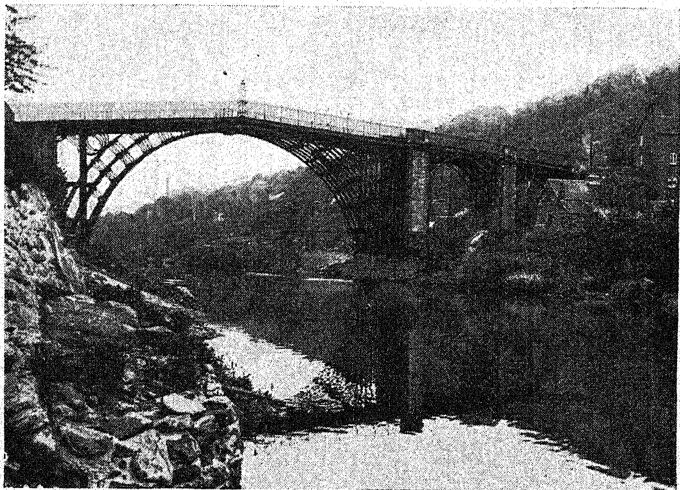
THE location of the iron and steel industry in the British Isles is very different in the twentieth century from what it was at the beginning of the eighteenth century. Two and a half centuries ago the main seat of the industry was the Weald of Kent, Sussex, Surrey, and the eastern borders of Hampshire. Iron ores were, and are still, plentiful in the Mesozoic rocks of that region, and the forests furnished the charcoal which was then the fuel used. Other regions for the early industry were the Forest of Dean, the Forest of Arden (in Staffordshire and Worcestershire), South Yorkshire, Durham, and the Furness Division of North Lancashire. The location of the industry was largely determined by the supply of timber for making charcoal, and the prosperity of the early iron-smelters in the fifteenth and sixteenth centuries resulted in such raids on the woodlands that legislation began to restrict the cutting of trees for charcoal-burning.

In addition to the two obvious factors, the presence of iron ore and the means of obtaining charcoal, another factor began to play an important part. Mechanical blowers came increasingly into use, and bigger furnaces thus became possible. The smelters, therefore, began to erect furnaces in glens or on hillsides where they could secure falling water as the power to drive their bellows. These conditions held until the progress of invention had shown how coal or coke could be used instead of charcoal as the smelting fuel. It is said that the early smelters of the Sheffield and Rotherham district, the Furness region, and the Middle Severn owed much of their progress and success to the abundant water-power of their upland valleys.

The great change came in the eighteenth century, between about 1709 and 1780, although there had been attempts to

smelt iron from its ores by means of coal in the seventeenth century in both England and Scotland.

The river Severn flows across the middle of Shropshire, from west to east, until it bends southward, after passing through the Severn Gorge, between the Wrekin and Wenlock Edge. On the eastern side of the gorge a little valley, with its small stream, descends sharply to the Severn. This is



THE IRON BRIDGE AT IRONBRIDGE, SHROPSHIRE
Photo James's Press Agency

Coalbrookdale, the Mecca of all who are interested in the iron industries of Britain. Here the Lower Coal Measures come to the surface; there is iron ore in the shales, and the Wenlock Limestone of Silurian age is close at hand. It was at this spot, in all probability, in about 1709–10, that iron was first successfully smelted by means of coke. There has been much dispute about the matter, but the letter of Mrs Abiah Darby, written about 1775, would seem to settle the question finally. She tells how her father-in-law, the first Abraham Darby, "first try'd with raw coal as it came out of the Mines, but it did not answer. He not discouraged, had

the coal coak'd into Cynder, as is done for drying malt, and it succeeded to his satisfaction."

It was in this same historic region that Abraham Darby the Third erected his famous iron bridge in 1779. This bridge was made and erected to cross the Severn, and to connect Broseley and Madeley, places then famous in the coal and iron industries. The historic bridge, the earliest iron bridge in the world, still stands, and the name of the place is Ironbridge to this day. It was here also that John Wilkinson, the "Iron King," built his iron barge to carry goods down the Severn.

Little was heard of Darby's discovery for a time, and for nearly half a century charcoal was still used for smelting the best grades of iron, as had been done in Sussex, the Forest of Dean, Cannock Chase, South Yorkshire, Furness, Cumberland, Durham, Central Scotland, and a few other places from time immemorial. The English iron industry had been declining from the middle of the seventeenth century; but as Abraham Darby's process became better known, and as other improvements followed, Britain rapidly went ahead, and by the end of the eighteenth century she had taken first place, only to lose it within comparatively recent years.

From 1709 onward the continued investigations and applications of the Darbys at Coalbrookdale, the work of Huntsman of Sheffield in about 1770, the work of the Walkers of Rotherham, of Roebuck and Garbett at Carron, in Scotland, of the Guests in South Wales, and that of the three Wilkinsons (Isaac, the father, and John and William, the sons) in Furness, in Staffordshire, in the Severn Valley, and at Bersham and Brymbo, in North Wales, and afterward the inventions of Henry Cort of Lancaster, about 1784, finally shifted the iron industry from the charcoal districts to the coalfields and gave to Britain that supremacy which was maintained for a century. Mass production in the iron and steel trades almost completely displaced the older and more scattered small-scale industry, and Britain led the world in production.

The above-mentioned John Wilkinson is often called the greatest of the early ironmasters. At the little village of

Lindale, near Grange, in North Lancashire, there is an iron column in a neglected enclosure, the walls of which are partly broken down, the inside grown over with docks, nettles, and other weeds. On this iron column the visitor may read:

JOHN WILKINSON
IRON MASTER
Who died XIV July, MDCCCVIII,
aged LXXX years.

His different works in various parts of the Kingdom are lasting testimonies of his increasing labours; his life was spent in action for the benefit of man; and, as he presumed himself to hope, to the Glory of God.

Labore et honore

This column has been removed from where it was first erected, and now stands not far from the spot where John and his father, Isaac, had owned a small works in the forties of the eighteenth century. Here they smelted iron, and here John had planned a canal in the turf, which he 'puddled,' and an iron boat carried the peat fuel to the works. Later on John astonished the world of his day by successfully launching his iron barge on the Severn, in 1787; his greatest work was, however, in collaboration with Boulton and Watt, the great builders of steam-engines. He bored cylinders much truer than any of his contemporaries seemed able to do, and Boulton and Watt were so well satisfied with his work that for many years they stipulated that the Wilkinsons should make the cylinders for the steam-engines erected by them.

John Wilkinson was a type of the restless inventor of his day, and his influence was so great that he became known as the "Iron King." Without subscribing fully to the eulogy on the Lindale monument, it is possible to say that he (with his father and his brother William) played a great part in the development of the early iron-smelting and engineering industries in Britain.

The nineteenth century saw many new processes introduced, the main aims of which were to increase the scale of output, to use ores which had hitherto seemed impossible,

to economize coal, and to produce different qualities of iron and steel suited to many varied uses. Most of these changes were initiated in Britain, and they further altered the geographical distribution of the industry. First of all, the industries became more and more concentrated on the great coalfields, and then later the tendency was to smelt the iron either near the ports or where the British ore is found. Some of these changes will be indicated later, in the regional study of the industry.

James Beaumont Neilson

Four of these inventions or modifications may be fittingly mentioned in this general geographical study. The first was the hot blast, introduced by James Beaumont Neilson in about 1828. The cold blast under pressure had played a great part in the revolution of the eighteenth century; Neilson's discovery brought about a tremendous saving of fuel, and a large increase in the possible output. The second great invention was that of Henry Bessemer, in 1855–56. The cast iron out of which steel was made contained many impurities, which had to be burned away. Bessemer conceived the idea of doing this in a huge 'converter,' containing from five up to twenty tons of molten iron; into the charge in this converter cold air under high pressure was blown. The temperature was raised enormously by the oxidation of the carbon, silicon, and manganese, and the mass became a white-hot melt of nearly homogeneous composition. The whole operation in the converter needed only some ten to twenty minutes, or in some cases even less. This new process revolutionized the steel-making trade, especially in the cheaper grades of steel. It was in Sheffield that Bessemer set up his works, and from his process came much of the steel which for thirty years or so dominated the industry.

About the year 1870 a number of firms began to make steel in what is called the open-hearth process, and for many years there was a keen battle between the Bessemer process, with its huge, bottle-shaped converter, and the Siemens-Martin open-hearth process. In the latter process there is more opportunity for testing the product and for rigidly controlling its composition; more scrap iron can be used, and of this there is always an abundance to be had; and also there is little or no loss by oxidation of iron. This process has therefore gradually displaced the once all-conquering Bessemer method, and now most of the British steel is made by the Siemens-Martin process.

SIR HENRY BESSEMER

Both the Bessemer and the Siemens-Martin processes had their limitations, because pig-iron containing much phosphorus could not be used; this meant that phosphoric ores could not be used for the making of pig-iron intended for steel manufacture. Phosphoric ores are very plentiful in Britain, and non-phosphoric ones not so common. A momentous discovery was made in 1878–79 by the joint labours of two cousins, Sidney Gilchrist Thomas and P. C. Gilchrist, the former a magistrate's clerk in London and an amateur student of chemistry, the latter a chemist at the Blaenavon Works in South Wales. These two workers showed that by lining the steel furnaces with dolomite the phosphorus was absorbed, and so these ores were at once brought within the scope of the smelter. These four inventions or adaptations brought the great industry up to quite recent times, and provided a starting-point for the next series of discoveries, which have come within the last fifty years, many of them within the last twenty-five years. One of the newer processes

is entering into competition with the open-hearth steel process and the older Huntsman processes; this is the electric furnace, which in Britain is mainly used for the production of special qualities of steel, and up to the present accounts for a relatively small proportion of British steel. The electric iron-smelting furnace has made more progress abroad. The special steels mentioned are the products of the last fifty years, and consist of alloys of other metals or non-metals with iron; each type possesses some special property, which has proved of immense importance in the recent development of various branches of engineering. Sheffield has been particularly associated with many of these new 'steels.' Hadfield's manganese steel, invented in 1882, was one of the first, and offered to the engineering world an extremely tough and hard steel, and one which had also the valuable property of being non-magnetic. Other special 'alloy steels' are silicon steel, of great value in certain kinds of electrical work, nickel steel, chromium steel, and nickel-chromium steel, all possessing high tenacity. Yet another is tungsten steel, used for making cutting tools which have to stand a high temperature. Chromium steel resists rusting and other forms of corrosion or staining. Steels which will not rust, stain, or tarnish have long been a *desideratum* in the steel industry. At first stainless steels proved very difficult to 'work' in the various engineering processes, but now Sheffield has overcome most of the difficulties, and steels which will not stain or rust can be obtained in the form of sheets, rods, tubes, bars, and wire. A new era in the use of steel has thus been opened up.

After this brief historical sketch it seems advisable to proceed to a regional geographical study of the production of iron and steel.

Pig-iron Manufacture

At the outset a short summary of the chief processes and materials may be given. The fundamental process is the smelting of iron ores in the presence of coal or specially prepared coke and limestone or lime as a flux; this process is carried on in the blast-furnace, and the product is *pig-iron*,

which is thus the basic substance for all later processes. Such pig-iron is of three grades or varieties—pig-iron intended for steel-making (which uses by far the greater part of the pig-iron produced), pig-iron for foundry purposes, and pig-iron for the forge, in which wrought iron, a comparatively pure and tough kind of iron, is produced. The pig-iron made from hæmatite is often specially named 'hæmatite pig.' Three fundamental raw materials have thus to be taken into account—iron ores, coke (or coal), and the flux; the distribution of blast-furnaces and of furnaces for steel-making is governed by the occurrence of these three raw materials and by the cost of transport of the raw materials and the finished products.

British iron ores are almost exclusively derived from three geological horizons. The Carboniferous Limestone, which is the lowest formation of the Carboniferous system, contains hæmatite (Fe_2O_3) in irregular pockets in Cumberland, Westmorland, and North Lancashire. The shales of the Coal Measures often contain nodules and irregular bands of impure carbonate of iron ($FeCO_3$); the beds are known as 'blackband ironstones'; the rock itself is often described as clay ironstone. These ores are still extensively worked in North Staffordshire. The chief part of the British iron ore is now obtained from the belt of Jurassic rocks which extends through Central England from north-east to south-west; here the ore occurs in irregular layers or beds, and consists of impure brown iron ore, or limonite ($Fe_2O_3 + 3H_2O$), and impure carbonate of iron ($FeCO_3$). From this Jurassic belt there was quarried and mined 89 per cent. of the 12,700,000 tons of ore produced in the United Kingdom in 1936; the Carboniferous Limestone rim of the Lake District produced 6 per cent., and Staffordshire, Shropshire, South Wales, and Scotland (from their blackband ironstone), 3 per cent. The 12,700,000 tons of British ore was supplemented by 5,960,000 tons of imported ore from other countries, chiefly from Sweden, Norway, and Spain; 7,400,000 tons of iron ore were imported in 1913. There is a remarkable difference in the iron content of imported ores and British ores: the metallic content of the British ores

varies from 20 to 60 per cent. That of the Scandinavian ores is normally 70 per cent. or more, but these are largely phosphoric. The Spanish ores, which are non-phosphoric,

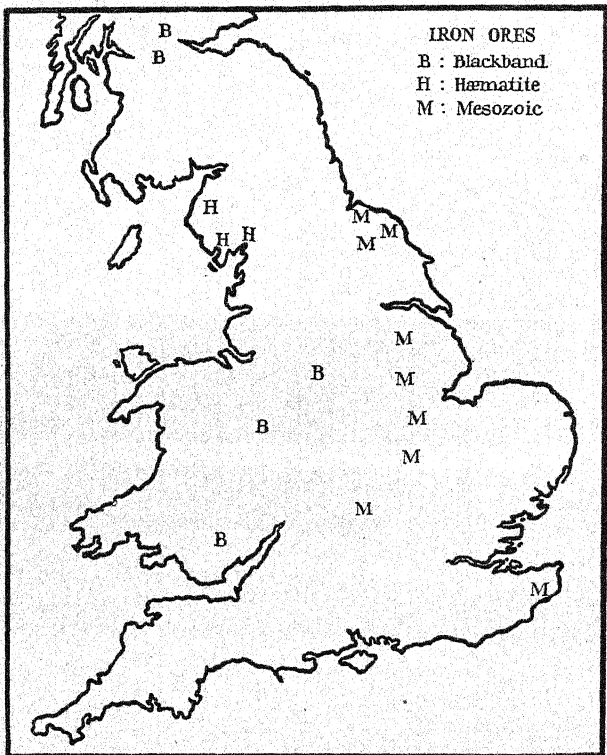


FIG. 13. IRON ORES OF THE PRESENT DAY

B, the blackband ores of the Coal Measures; *H*, the hæmatite ores of the Carboniferous Limestone; *M*, the varied ores of the Mesozoic rocks.

are about 60 per cent. metallic. Obviously it would not, as a general rule, pay to bring ore from some other country if it yielded only the same proportion of pig-iron.

In the earlier days of mass production of pig-iron it was, as a rule, considered more economical to carry the ore to the coal, but now the tendency is to move the coal or coke to

the ore; hence Cleveland, North Lancashire, Lincolnshire, East Leicestershire, and Northamptonshire, taken together, produce more than half the pig-iron of Great Britain, al-

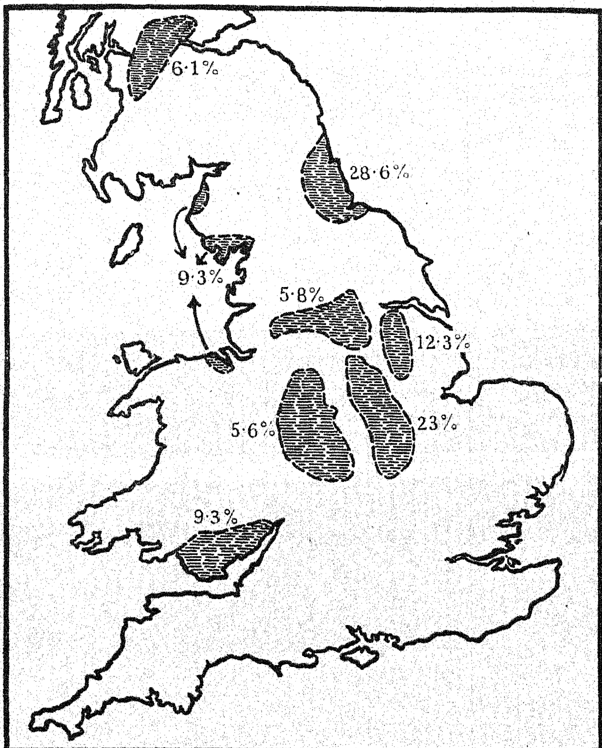


FIG. 14. THE PIG-IRON INDUSTRY

The amount of pig-iron produced in Great Britain in 1936 was 7,721,000 tons. This map shows the regions of production, with the approximate share of each.

though coal does not occur there. Other important districts for blast-furnaces are the coalfields of Yorkshire, Derbyshire, and Nottinghamshire, Durham and Northumberland, West Cumberland, Staffordshire, Worcestershire, and Shropshire, South Wales, Monmouth, and Gloucestershire, North Wales and Central Scotland. There were about 245 blast-furnaces

in existence at the end of 1936, of which possibly about 110 were working. The largest number of big furnaces was in the North-east of England and in South Wales and Monmouth; Central Scotland has mainly blast-furnaces of the smaller type. There are almost as many furnaces in Scotland as in the North-east of England, but those of the latter region turn out more than three times the quantity of pig-iron produced by the Scottish furnaces.

The Production of Steel

This is often still carried on quite apart from the production of pig-iron, but there is a considerable tendency to bring the steel manufacture close to the blast-furnaces; in fact, in many cases now the molten iron is carried directly from the blast-furnace to the steel furnace, and the operations are, so to speak, under the same roof. It is not possible, however, to make any absolute statement, as so much depends upon a number of variable factors. The North-east of England has a large number of big steel furnaces, mostly of the open-hearth type; in Scotland there are many big steel furnaces and a few very large ones. Sheffield has a somewhat specialized type of steel industry; there are several large steel furnaces (not of the very greatest capacity) and many small ones, in which are produced the special alloy steels for which Sheffield has become so famous. In 1937 a total of nearly 13,000,000 tons of steel was produced in Great Britain, and four districts accounted for nearly 70 per cent. of this output. In 1938 the output fell to 10,394,000 tons.

The reader will now have gained a general idea of the distribution of the two major processes. It may be of interest to mention a few general tendencies and some peculiarities of that distribution. There has been a great decline in the production of puddled or wrought iron, because the process is both costly and laborious, and steel has been found to be an efficient substitute for many purposes. Fifty years ago the output of wrought iron from pig-iron was over 2,500,000 tons; in 1925 it had come down to about one-tenth of that amount.

The Bessemer converter, once so famous and so important, is gradually being replaced by the Siemens-Martin open-hearth process. In 1877 the amount of Bessemer steel produced in Britain was about five times that of open-hearth steel; in 1887 it was about twice as great; in 1892 the amounts were about equal; in 1902 open-hearth steel was to Bessemer steel as 5 : 3; in 1912 open-hearth steel was about three-fourths of the total steel produced, and in 1929 Bessemer steel had dropped to about one-eighteenth of the whole. This shows how keen the student of geography must be if he would follow the general trend of technical changes.

Another interesting and typical study is in the general work of Sheffield. This city and the immediate district is the home of an immense and highly specialized steel industry, but not of iron-smelting. Farther away, and within fifty miles of Sheffield, an immense amount of pig-iron is produced, and yet not much even of this is used in the manufacture of the steel for which Sheffield is so famous. The highest quality Swedish iron is demanded by most firms engaged in the steel-cutlery industry of that city, for which very high-grade steel is needed. To quote Lord Aberconway, "Sheffield steel is the dream of competitors; and the Sheffield steel furnaces dwarf even the famous Krupp works at Essen."

A large measure of co-operation with the State was achieved by the iron and steel industry with the inauguration of the British Iron and Steel Federation in 1934. The tradition of individualism previously recognized had endangered the integrity of the trade, and complete internal reorganization was made a condition for the erection of a protective tariff. Rearmament projects have also assisted heavy industries. As a result the iron and steel industry is now better equipped than it has ever been to resist successfully a temporary economic depression. It is obvious that Britain no longer exports large quantities of either pig-iron or steel ingots; in fact, her imports of both these 'raw materials' are now considerably greater than her exports. Pig-iron and steel bars are being increasingly regarded as 'raw materials.' This is but one phase of the general tendency to work up raw materials rather than to produce them.

CHAPTER XI

IRON AND STEEL MANUFACTURES: ENGINEERING AND MACHINERY

THE next inquiry is: What becomes of the iron and steel which are made in furnace, foundry, and forge? Here the study enters on another phase. There is no hard and fast line between the industries discussed in this and preceding chapters; also, when the production of iron and steel goods is discussed it is not possible to have absolute and clear-cut distinctions. For practical purposes, however, a rough division is possible into (i) castings or mouldings, to which very little remains to be done; (ii) the production of what may be called semi-manufactured goods; and (iii) tools, implements, machines, and engines.

The casting, rolling, and forging of iron and steel gives, in the first place, such products as cast-iron pipes and other cast- or wrought-iron hollow ware, stoves, fire-ranges, grates, baths, steel plates, wrought-iron sheets, steel girders, joists, beams and angles, anchors, framework for machinery, and other forms of cast and moulded iron. More and more of these goods are being made of steel and less and less of puddled or wrought iron, as already stated. The foundry still produces refined cast iron from pig-iron, and there is scarcely any considerable town in the country which does not contain at least one foundry; and every industry and trade is dependent on the founder's art. The things produced may be tiny brackets for shelves, or huge water-pipes, such as bring the water from Thirlmere to Manchester, or even the 'tubes' for the London underground railways. Derbyshire, Staffordshire, Worcestershire, and Warwickshire specialize in the large-scale production of tubes, baths, tanks, and other hollow ware; Derbyshire, Nottinghamshire, the West Riding, Lancashire, and Staffordshire produce stoves, fire-grates, ranges of various kinds; while for sheets for 'tinplate' one

turns to South Wales and Monmouth, and for sheets for galvanizing to North Wales and South Wales and Monmouth.

Only a stage removed from the above iron and steel productions are such things as chains, wire, wire-netting, wire rope, wire mattresses, bolts, nuts, screws, rivets, nails, and tacks; with wire and wire mattresses go steel tubes for making bedsteads, and there are many similar interrelationships. These specialities are not so widespread as the general foundry work just mentioned; South Staffordshire and Worcestershire make chains and anchors; the same regions make nails, tacks, iron bedsteads, and wire mattresses; for wire, wire rope, and wire-netting one goes to the West Riding, South Lancashire, Derbyshire, and Nottinghamshire; while bolts, nuts, rivets, and screws are made in the West Riding, Staffordshire, Warwickshire, and Worcestershire.

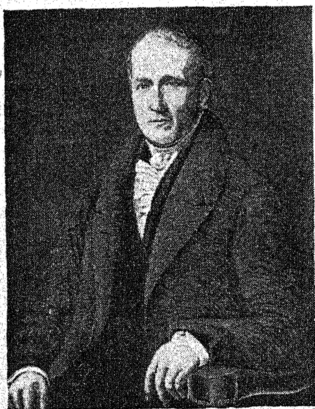
Farther removed still from the original raw material is the manufacture of tools, implements, machines, and engines; and this branch of the industry is more specialized and more definitely localized. Taking the engineering industry as a whole, one notices that it is represented in all parts of the country, but there are especially busy regions in Lancashire (the Manchester province), the West Riding of Yorkshire, the North-east of England, in the Clyde region and Central Scotland, in the Midlands (the Birmingham province), in South Wales, and in Greater London. Some local specializations are at once apparent, such as agricultural machinery in the eastern counties, cutlery and small-tool manufacture in Sheffield and district, mining machinery in Scotland, the North-east of England, and Lancashire, machinery for the textile manufactures in Lancashire and the West Riding, motor and cycle manufacture in the Midlands and round London; but none of these statements must be interpreted too rigidly.

Regional Study of the Engineering Industry

The Manchester Province. The Manchester province is probably the greatest engineering district in the world. The peculiarity of this great province is that it produces very

little crude iron or steel; the hæmatite and rolling-mills of the North-west are in an entirely different province. The engineers of the Manchester province draw their supplies of malleable or wrought iron and steel mainly from Yorkshire and the Midlands.

Textile engineering is naturally one of the foremost branches of this great industry. When Isaac Dobson came down into Lancashire from Patterdale, in 1790, and commenced the manufacture of spinning machinery he was building bigger than he could have imagined; the firm he started is the famous one of Dobson and Barlow, of Bolton, and in that great and typical Lancashire town there are about 9000 men engaged in the engineerng trade, 5500 being employed by Messrs Dobson and Barlow alone. The great Bolton firm claims to be the oldest textile engineers in the world. Their position and influence in the history of the textile industry are summed up in the words "Famous since the days of Crompton." Messrs Platt Brothers and Company, of Oldham, is a still greater concern, and employs in fairly prosperous times about 12,000 workers. Draw a line across Lancashire from Preston to Warrington, and every Lancashire town east of that line has some share in the great industry of making textile machinery. For example, Burnley, in the north-east of the county, has no exceptionally large works, but it claims to turn out more looms in normal times than any other town in the world. In addition to the three towns already mentioned, there are great works for the making of textile machinery in Manchester, Salford, Ashton-under-Lyne, Bury, Rochdale, Blackburn, Accrington, and Colne. These works, of course, make machinery not only for the home market, but for the whole



ISAAC DOBSON
By courtesy of Messrs Dobson and Barlow

world; many of the well-known firms will equip a cotton-mill in India, China, Japan, Brazil, or in a European country. The activities of these busy Lancashire workshops has made possible the foreign competition about which the spinners and weavers of the cotton-manufacturing trade complain so much to-day.

The Manchester province also leads the world in production of electrical machinery, and there are many great firms which confine themselves to this class of work. Other important branches of engineering, in the wide sense, are steam-engines, gas-engines, oil-engines, crushing and grinding machinery, pumps, machinery for boring and drilling, steam-boilers, laundry machinery, printing machinery, equipments for coke-making and by-product recovery, steam-hammers and rolling plant, motor-cars, motor-wagons, road motor-coaches, aeroplane plant, railway equipment, including locomotive engines, flour-milling machinery, mining machinery, and a host of minor but still very important things.

The Leeds, Sheffield, and Nottingham Province. Across the moors from the immediate Manchester district is the great engineering province which lies mainly on the Yorkshire, Derbyshire, and Nottingham coalfield; this huge province ends sharply a little north of Leeds and to the south of Nottingham, and is thus fairly coterminous with the coalfield. First of all, there are the articles made in the Sheffield district, both from the Sheffield steel and from wrought and foundry iron made elsewhere. Sheffield has its enviable reputation for the best cutlery and tools in the world; but it has also an immense manufacture of engine parts, steel plates, colossal castings of steel, and huge forgings of many kinds. The district demands steel of reliable composition and iron made from good hæmatite ores, and it is remarkable that there is still room in the trade for the small makers of crucible steel, descendants of the men who founded the trade some centuries ago.

It is to the credit of Sheffield that most of the new ideas in steel manufacture have been first tested in that city; the Huntsman process for making cast steel in 1770 made the first great revolution in the trade; this was purely a Sheffield

district advance. The Bessemer process and the Siemens-Martin open-hearth process were both quickly taken up by Sheffield; and the modern advances in alloy steels have been more closely allied with Sheffield than with any other place.

The Sheffield district is, so to speak, in the middle of the great engineering province which stretches from Leeds to Nottingham, and which makes such a variety of products. In the north-west of this great region, in the Keighley, Bingley, and Bradford districts, are some of the most successful textile-machinery makers in the world; the firms made machinery in the eighteenth century for the woollen trade and for the rapidly developing cotton trade on the other side of the moors. One of the Keighley firms makes many looms not only for the West Riding, but also for the East Lancashire industry in coloured cotton goods; another firm makes everything connected with the whole field of wool-combing, drawing, spinning, and weaving. Farther east, at Leeds, machinery for the linen, jute, and ramie trades is also made.

Leeds is a great iron town, and an important engineering centre. It is on record that an early maker of locomotive engines built his first one in an old mill at Hunslet, and had to pull down a part of the wall to get the engine out. Railway engines and railway plant for all parts of the world have been made in the Leeds district. It is claimed that the first successful steam-plough was made in Leeds, and agricultural machinery has continued to be made there in considerable quantity. Famous firms in the West Riding date back a long way; the blast-furnaces at Low Moor were founded about 1788, and they supplied the region with a very high grade of iron, which was much in demand for over a hundred years. The Kirkstall forge, close to the famous abbey, was founded about 1779. There are many other famous developments of nineteenth- or even twentieth-century origin; one example of the latter is the building of commercial motor vehicles in Huddersfield. In short, the great province, in its Yorkshire division, makes an immense variety of products; the list may be closed by instancing,

FIG. 15. DIAGRAM MAP OF THE CHIEF ENGINEERING REGIONS AND SOME OF THE MORE IMPORTANT ENGINEERING TOWNS IN GREAT BRITAIN

merely as types, sewing-machines at Keighley and monster gas-holders at Leeds.

Nottingham city lies in the south of this great province; here are other branches of the engineering industry, where motor-cars and bicycles, lace-making, stocking-knitting, and other highly specialized machinery are made.

The Newcastle-Middlesbrough Province. A great variety of iron and steel goods are made in this province of over two millions of people; the excellent coke (practically free from sulphur and phosphorus), the ironstone of Cleveland, and the limestone of the Pennines have called into being a vast number of interrelated iron and steel industries. Industry extends from north of Newcastle to south-east of Middlesbrough, and the products are varied. Steel castings for bridges, buildings, masts; cast-iron segments for the London underground railways; plant for gas companies, blast-furnaces, and coke ovens; excellent forged shaftings for many purposes; marine boilers and engines; the famous turbines of Tyneside (the home of the steam-turbine); locomotives; freezing plant for cross-oceanic shipping; tanks, locomotive wagons, pumps, winches, deck machinery, cables, wire ropes, steering-gear—these are some of the very varied productions of this north-eastern region. The connexion with shipbuilding will at once be obvious; this subject is more fully treated in Chapter XIII.

The Central Scotland Province. This region has a great history in the iron industry; the Carron Company proudly advertises "Founded in 1759"; and one must remember that it was in Scotland that Neilson's hot blast was first applied; he filed his patent in 1828, and by 1835 practically all the ironmasters of Scotland were using the hot blast. James Beaumont Neilson was a Scotsman and a student of physics and chemistry at Anderson's College, Glasgow.

The province is almost a rival of the Manchester province in the production of heavy machine tools; its output includes lathes, screwing machines, grinding machines and presses, and mining machinery. More than half the locomotives made in Britain, outside the great railway companies' own works, are made in the Glasgow area. Many famous iron and steel

girders and other bridge structures stand to the credit of firms in this region; among them are the Forth Cantilever Bridge, the second Tay bridge, and the Tower Bridge over the Thames. Of course, a great deal of the plant and the energy, as in the case of North-eastern England, is directed toward shipbuilding.

The Birmingham Province. Here is to be found the most varied metallurgical industry in the world, and the district which has Birmingham for its centre is known the world over for the variety, the vast extent, and the excellence of its metal wares. The descriptive term 'engineering' applies perhaps less here than in the other provinces dealt with. Many great names have been associated with the production of wrought iron and steel in this region and with the working up of these into the varied articles for which the region is so famous. It was in 1774 that James Watt removed to Birmingham, and in 1775 the firm of Boulton and Watt of the Soho Works began their long and famous output of steam-engines. They did not make engines for sale, but erected them for their clients; John Wilkinson made the cylinders, and Boulton and Watt supplied the accessories and erected the engines. Watt wrote in the nineties of the eighteenth century: "In the course of 20 years we have not erected more than 3 or 4 engines of which the cylinders were not of his [John Wilkinson's] manufacture." It is perhaps fitting that the standard portrait of the great ironmaster is one of the treasures in the Town Hall of Wolverhampton.

MATTHEW BOULTON

The Birmingham province is the home of the general 'hardware' trade, and the variety of goods made from cast and wrought hollow ware, and from iron and steel plate, is

amazing. The list includes nuts, bolts, screws, rivets, iron and steel tubes, stoves, grates, and ranges, locks, keys, and latches, small and large chains, cables, anchors, spades, shovels, picks, forks, hammers, chisels, nails, hooks and eyes, steel pens, and japanned goods of all descriptions. To these, and in another group, one may add lathes, drilling machines, milling and stamping machines, power presses, and machinery for wire-drawing; railway rolling stock and rails; motor-cars and cycles; steam-, gas-, and oil-engines; cooking utensils; and an immense variety and range of electrical apparatus. At almost every point the Birmingham province brings in other metals to supplement iron, and this phase of its variety will be mentioned in a later chapter.

The South Wales Province. This region, with which Monmouth is naturally associated, has had many famous names connected with it, and some of its works are historic. The Dowlais furnaces, now moved nearer to the coast at Cardiff, date from 1757, and the famous Ebbw Vale furnaces were started about 1793. Some of the firms bear names which are known the world over, such as Guest, Keen, and Nettlefold, and Baldwin's, Ltd.[1] A list of the chief productions of the latter firm gives a good summary of the chief activities of South Wales in this direction: pig-iron, steel ingots and castings, semi-finished steel, rails and small sections, light plates, sheets for galvanizing and tinning, and tubes. The two great firms mentioned as types have works in other parts of the country as well.

Engineering in Greater London. During the last fifty years many old-established engineering firms have migrated from London and established themselves in the provinces. Some of the places favoured by the migrating firms have been Luton, Rugby, Peterborough, Chesterfield, and Newark. Some of the once famous firms have disappeared altogether. There are, however, many firms still in the Greater London area, some of them of quite recent origin, who make specialities in machinery and tools, and assemble machine parts which are made in the Manchester province and in the Midlands. Woolwich Arsenal does the finishing of forgings

[1] Amalgamated to form the British Iron and Steel Company in 1930.

and castings for ships which have been made in the North; it also does repair work, and serves as a training school for gunners and field engineers.

There are many engineering works which do extensive repairs, such as those of the Port of London Authority, the London Passenger Transport Board at Ealing, and the depots of the Metropolitan and District Railways. Electrical work is widespread and varied, but it is mostly specialized.

The Scattered Machinery Manufacture of the Eastern Counties. This is one of the most surprising, and, perhaps, one of the most unexpected, groups of engineering industries in Britain. The region is so closely associated with agriculture that it comes as a surprise to many to learn what a great number of large and famous works are to be found in the bigger towns of these eastern counties. Agricultural machinery, in the widest sense, has laid the foundations, but to this have been added road tractors, road rollers, refuse carts, portable engines, steam rail-coaches, cranes, steam-boilers, steam-navvies, and other excavating machinery. A steam-navvy made in the eastern counties lifted with ease more than 1000 tons of earth a day in the making of the Manchester Ship Canal.

The chief towns, taking them from north to south, are Gainsborough, Lincoln, Sleaford, Grantham, Peterborough, King's Lynn, Norwich, Thetford, Leiston, Bury St Edmunds, Ipswich, and Colchester; but there are foundries and machine works in many other towns. It is calculated that at least 20,000 men find employment in normal times in the engineering works of these eastern counties. Probably Lincoln takes first place in the group in so far as these industries are concerned.

Railway Engineering. This is largely done by the railway companies themselves, and their works are scattered throughout the country. The chief places where locomotives are built and repaired are Swindon, Crewe, Derby, Horwich, Kilmarnock, Glasgow, Gateshead, Darlington, Gorton (Manchester), Stratford (London), Ashford, in Kent, Brighton, and Eastleigh, in Hampshire. Carriage works, wagon works, and general repair 'shops' are at some of the above-mentioned

places and at Wolverton, Earlstown, Wolverhampton, Newton Heath (Manchester), Stoke-upon-Trent, York, Dukinfield (near Manchester), and Caerphilly, in South Wales. In that excellent weekly journal *Modern Transport*, January 5, 1929, there was a most interesting set of illustrations of British-made locomotives for overseas railways which had been built in Great Britain in 1928. The engines had been made at Glasgow, Newcastle, Darlington, Gorton (Manchester), Patricroft (Manchester), and Newton-le-Willows. They were for use on the railways of India, the Malay States, New Zealand, South Africa, Nigeria, Egypt, and the Argentine. This is given as an example of what private engineering firms can do.

The foregoing account of the main engineering provinces and of the scattered railway works by no means exhausts the list of engineering towns. Places such as Carlisle, Chester, Leicester, Crayford, Croydon, Chatham, Portsmouth, Southampton, and Plymouth, which are not closely associated with any coalfield and are at least some distance from any blast-furnaces or steel-works, all have engineering firms of considerable importance. In this connexion the statement made on page 130 may be recalled, that there is scarcely a town of any size or importance which does not contain at least one iron foundry.

There remains the question of British imports and exports of engineering productions in the wide sense. The home market is exceedingly important, and to supply it adequately needs a great organization. The home market is not enough to absorb all that this necessary organization is capable of turning out, and Britain must export, and export largely, to help to pay for her vast imports and to keep her workshops fully employed. It is convenient to take the various groups of iron and steel manufactures together with those of other metals. There are five main groups given in the usual lists of exports of manufactured articles: (i) iron and steel manufactures; (ii) non-ferrous metals and manufactures; (iii) cutlery, hardware, implements, etc.; (iv) electrical goods and apparatus; (v) machinery. These five groups made up a grand total of £122,000,000 average value in the two normal

years 1936 and 1937. The group taken as a whole came next in value to the exports of textiles,[1] which averaged £131,200,000 for the same two years, the biggest value of any group of exports from the United Kingdom.

The best customers for British machinery are the various countries of the British Empire, who took 47 per cent. of the value of the exports in 1925, followed by European countries, taking 27 per cent., and South America, which took 10 per cent. Very little is now exported to the United States of America, and not a large amount to China and Japan. Of the greater British Dominions the customers for all types of machinery came in the following order: British India, Australia, the Union of South Africa, New Zealand, and Canada. The low position occupied by the last-named is largely due to her proximity to the United States; it is obviously much easier to transfer locomotives, road tractors, motor-cars, and other vehicles from the United States into Canada than it is from Britain.

One particular branch of engineering is noteworthy for the remarkable increase that has taken place in both production and export in quite recent times; this is the manufacture of motor-cars and other vehicles, motor and pedal cycles. The total number exported in 1910 was 136,566, but in 1937 this had mounted to 493,000, or over three times as many.

[1] Including apparel.

CHAPTER XII

METALS OTHER THAN IRON (NON-FERROUS METALS)

THE merest glance round the home, the office or shop, the factory or workshop, the school or college, the tramcar, omnibus, or railway coach, reminds one that although iron is justly named king of the metals the other metals play very important parts in human affairs. Even rare metals, such as iridium and thorium, which the average man rarely sees in the metallic condition, are becoming year by year more important. Platinum, gold, and silver need little emphasis, and will receive only incidental mention in this study of Industrial Britain. The main part of the present chapter will be concerned with the metals which were once called the 'base metals'—copper, tin, lead, zinc, and nickel—and with some others whose importance is quite modern, such as tungsten, chromium, manganese, and aluminium.

Copper. Near Amlwch, in Anglesey, is a low hill called Parys Mountain. In that hill is a copper-mine of great age and of considerable interest; its output actually dominated the world's copper markets for many years over a century ago. Underground working has now ceased, but some copper is still obtained, chiefly from old dumps, by a leaching process.

Another famous mine is at Dolcoath, in Cornwall, from which tin is also obtained. It is said that copper to the value of £2,500,000 sterling has been obtained from this mine in the past. A third British copper-mine of some historic interest is at Ecton, on the borders of Derbyshire and Staffordshire; for it was there that drilling and blasting were first used in any British mine. There are other scattered occurrences and mines of copper, employing only a small number of men, in Devon, mid-Wales, the Pennines, the Lake District, the Wicklow Hills, and the Triassic sandstones of Alderley Edge,

Cheshire. The production of all these mines amounts only to a small part of the vast needs of British industries to-day.

In 1936 the United Kingdom produced 62 tons of copper from its own ores, while in the same year the United States of America produced 611,409 tons. The United Kingdom imported over 31,000 tons of ore, matte and precipitate, which is five hundred times its own production, while the vast amount of 250,000 tons of copper, in the form of bars, blocks, ingots, plates, tubes, and wire, were imported. The dependence of Britain upon imported copper is almost complete.

The world's chief producers of copper ore (upon whom Britain depends for her supplies) are the United States of America, Chile, the Belgian Congo, Japan, Canada, Mexico, Spain, Germany, and Rumania. The British Empire produced 201,000 tons of copper ore in 1931, which was about 14 per cent. of that of the world.

Tin. This is a very important metal, which always commands high prices. There are few kinds of ore, and there seem to be only certain petrological regions where they occur in large quantity. The British Isles have been famous for tin for over two thousand years, but the supplies from British mines are now quite overshadowed by those from other parts of the world, and British metallurgical industries demand a big import from other lands. In 1936 there were 2099 tons of metallic tin obtained from British ores, which is a large amount compared with the copper, but nearly 52,000 tons of tin ore were imported.

There is one region only in Britain from which tin ore is obtained in some quantity, and that is the south-western peninsula. In Devon and Cornwall there are five big granite masses, and the tin ore occurs most profusely near the junction of the granite with the country rock. Tin-mining is of great antiquity in Devon and Cornwall, and it is thought by some that the ancient Cassiterides of the Greeks meant Cornwall. The industry was certainly important in the Norman era, and it continued, with periods of depression, through the later medieval era into early modern times. In the days of Queen Elizabeth miners were brought from

Germany to teach better mining methods and to develop the tin industry. In modern times the deposits of 'stream tin' have become almost exhausted, and the more costly deep mining has not always been able to compete with mines in other world-regions. The period of greatest prosperity in modern times was in the sixties and seventies of the nineteenth century; then came a big drop in the price of tin, and at the beginning of the Great War the output had gone down to one-half of that of fifty years earlier. There was then a short period of comparative prosperity, but in post-War years the decline set in again, and, as pointed out above, the British output in 1936 was somewhat over 2000 tons, compared with 14,000 tons in about 1870. The district about Camborne and Redruth has been the most famous tin-mining region in the British Isles, and Camborne has long possessed a school of mining. The tin ores of that region are associated with copper, lead, zinc, arsenic, tungsten, and smaller amounts of nickel, cobalt, gold, and uranium.

The chief world-producers of tin are the following: the Federated Malay States, Dutch East Indies, Bolivia, Nigeria, Siam, and Australia. Britain buys ore largely from the Federated Malay States and Nigeria.

Lead and Zinc. These two useful metals are quite dissimilar in properties, but their ores are frequently associated with each other, and with other metals. Many ores of lead contain silver; they are often spoken of as silver-lead ores. Many zinc ores contain the metal cadmium.

Lead and zinc ores are mined in the British Isles from two chief sources: (i) veins and pockets in the Carboniferous Limestone of the Northern Pennines, Derbyshire, North Wales, and the Mendip Hills; (ii) veins in the Lower Palæozoic rocks of Southern Scotland, the Lake District, Wales, Shropshire, the Isle of Man, and the Wicklow Hills, and from the Palæozoic rocks of Devon and Cornwall. Many of these lead ores contain silver, and the 76,885 troy ounces of silver produced in the United Kingdom in 1936 were largely from these sources.

Mining in the Carboniferous Limestone regions of the Pennines and North Wales was once a vigorous and profitable

industry, but now there is the same story of derelict mines and mining buildings almost everywhere. The industry is of great antiquity. Two pigs of lead bearing Latin inscriptions which showed that they were smelted and cast in A.D. 87 have been found near the once famous Greenhow Hill mines, not far from Pateley Bridge. There are many references to the Alston Moor, Weardale, Grassington Moor, and Derbyshire mines in writers such as Leland, Camden, and Defoe. The Grassington mines were in a flourishing condition at the time of the Great Exhibition in 1851, as were the Derbyshire mines. About 90 per cent. of the lead ore produced in this country comes from Mill Close mine, in Darleydale, Derbyshire, and Halkyn mine, in Flintshire. It is no longer possible to work profitably many of the northern mines. In 1936 29,000 tons of metallic lead and 3314 tons of metallic zinc were obtained from British ores; this is, of course, not nearly enough for British requirements, and large amounts are imported from the United States, Australia, and Spain.

Nickel. British ores containing this important metal can be regarded only as mere specimens. Britain has to import practically all that she needs. Nearly the whole of the imported ore and matte comes from the Sudbury mines, in Ontario, from which in 1928 about 90 per cent. of the nickel used in the world was obtained.[1] The ore is worked up at the nickel works near Swansea, by the process which was developed by the late Dr Ludwig Mond. Another important source of nickel is the island of New Caledonia, a French possession in the South-west Pacific.

Tungsten. This metal is now very important as a constituent of alloy steels which possess remarkable properties, and also of other important alloys. The United Kingdom produced 189 tons of tungsten ores in 1936, the chief source being Cornwall. The world's biggest producers are China, the United States, and Burma. The United Kingdom imported over 3000 tons of tungsten ores in 1931.

Chromium. This metal is widely distributed, but there does not seem to be much British production; the only ore that is much worked is chromite of iron. The needs of British

[1] From all Canada 82 per cent. in 1931.

metallurgy are met chiefly by imports from Southern Rhodesia, the Union of South Africa, Cuba, and New Caledonia. The ores are treated not only to obtain metallic chromium, which is needed for alloy steels and other alloys, but also to obtain chromate of potash, chromate of soda, and especially bichromates of the same metals. The United Kingdom imported 40,907 tons of chrome ores in 1936, practically all of which was used in the British Isles.

Manganese. This metal has passed, within recent years, from a position of comparative obscurity into the front rank. Ores of the metal occur in many forms and in several geological formations in the United Kingdom, but only three regions can claim to be moderately important. These are Rhiw, in Carnarvonshire, Llanbedr, in Merionethshire, and the tin-mining districts of Cornwall. No manganese has been raised in Britain since 1928; the amount previously varied considerably, 1924 standing out with 2457 tons to its credit. The present-day (1937) import is about 228,000 tons, chiefly from India and the Gold Coast. The value of manganese ore imported into the United Kingdom from India in three recent years averaged £612,000 per annum.

There is much manganese ore in Brazil, but this is bought mainly by the United States. Russia has rich deposits in the Caucasus region and the Urals, but little of it reaches the outside world at the present time.

Hadfields, of Sheffield, were the first firm to manufacture manganese steel, though to-day the largest import is *via* Middlesbrough and Liverpool.

Manganese is not only much in demand for the manufacture of manganese steel, but it also enters into a number of technical processes in Britain. Its compounds are used in glass manufacture, in dry batteries, for the manufacture of chlorine, and for the production of potassium permanganate and similar compounds widely used in staining, dyeing, and as disinfectants.

Aluminium. This is probably the most abundant metal in that part of the earth's crust which is accessible to man, but metallurgy has not yet solved the problem of extracting it on a commercial scale from such compounds and minerals

as some felspars, clays, etc., in which it exists in enormous quantities. The British mineral from which the metal is obtained is bauxite, a mixture of hydrated aluminium oxide

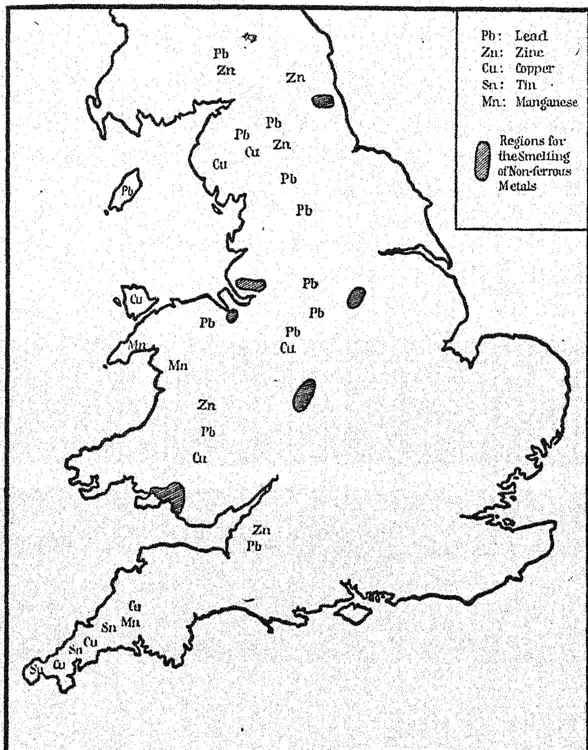


FIG. 16. THE CHIEF REGIONS IN WHICH LEAD, ZINC, COPPER, TIN, AND MANGANESE HAVE BEEN MINED, AND THE CHIEF REGIONS FOR THE SMELTING OF THESE NON-FERROUS METALS

and hydrate of iron; this mineral occurs in beds among the Tertiary volcanic rocks of Antrim, especially in the neighbourhood of Ballymena and Larne. Other supplies of bauxite come from France, Italy, Yugo-Slavia, British Guiana, and the United States of America.

The ore is mixed with cryolite, which is a double fluoride of aluminium and sodium, and possesses a low melting-point. This mineral is known in workable quantities only in Greenland. The mixture of bauxite and cryolite is subjected to electrolysis, and the metal is thus obtained. The process is mainly carried on where cheap electric power is obtainable, as at the Falls of Foyers, in Scotland, Dolgarrog, in North Wales, in Norway, and at Niagara Falls. The United Kingdom produced 14,000 tons of metallic aluminium in 1931, Germany nearly twice as much, the United States of America over five times as much.

The Smelting and Refining of the Non-ferrous Metals

This industry is carried on in South Wales, the Birmingham district, Sheffield, Newcastle, and South-west Lancashire. South Wales is the most important region, and has long been famous for the smelting and refining of copper, tin, zinc, and lead.

Three hundred years ago the copper-miners of Cornwall were sending their ores to Neath to be smelted. The Cornish tin-miners soon followed their example, and it was not long before the lead-miners of Cardiganshire followed suit. The district including Neath, Swansea, and Llanelly thus became famous for the skill of its workers in these metals.

At one time copper ores from all over the world were imported to Swansea to be smelted; over 2,000,000 tons came in 1865. Nowadays copper ore is usually smelted in the region where it is mined, and the once famous Welsh industry of smelting copper from the ore has practically disappeared. The South Wales workmen and masters are skilled in the working of copper, but they now buy impure copper, known as matte and regulus, which they smelt and purify. Another 'raw material' which South Wales now handles is the by-product copper obtained from the Mond nickel industry mentioned above.

Tin is smelted in the same region of West Glamorganshire and East Carmarthenshire, where the chief towns are Swan-

sea and Llanelly. A big works for the preparation of metallic tin has also recently been started in the neighbourhood of Liverpool.

The United Kingdom still imports tin ore much more largely than any form of pure or impure metallic tin, or, in other words, the tin-smelting industry is still very important. In 1936 there was an import of 52,000 tons of ore, against one of 5250 tons of tin in blocks and ingots. The *export* of metallic tin for the same year was 18,000 tons.

Lead and zinc are smelted in other parts of Britain as well as in South Wales. The industry, however, is not a great one. The lead ore imported into this country in 1936 was 34 tons, while the import of pig-lead and lead manufactures reached the figure of 335,000 tons. In the case of zinc, more smelting was done in Britain, for the imports of ore were nearly 130,000 tons, while the imports of spelter (crude metallic zinc) were 180,000 tons. Some of the biggest and most famous smelting-works are in South Wales. It is said, for example, that 95 per cent. of the spelter (zinc) is smelted and refined in that famous metallurgical region. Swansea fully merits the title sometimes claimed for it, the metallurgical capital of Wales.

Birmingham and district also smelts and refines zinc, and makes a speciality of metal of a high degree of purity. One Birmingham firm produces zinc guaranteed to contain 99·9 per cent. of the pure metal. Lead is also smelted and purified at Chester and Newcastle; and there are local lead-smelting works (mostly in disuse now) in several towns near the old lead-mining regions mentioned earlier.

The Sheffield and Birmingham districts, especially the latter, both carry on a considerable industry in refining and alloying many of the non-ferrous metals. Some of the brass-founders, for example, buy ingots of brass and work up the alloy; others buy copper and spelter (zinc) separately and mix and refine the alloy themselves. There is, of course, a vast range and an enormous variety of these non-ferrous alloys. An alloy of about 70 per cent. copper and 30 per cent. zinc is ordinary brass, but the proportions are varied a great deal for different purposes. Sometimes a little lead

or iron is added, so as to make the brass a little redder or browner in colour, or to make it easier to cut. Bronze is a name used for various mixtures of copper and tin, and again a proportion of another element is often added, such as zinc or antimony or phosphorus. A recent aluminium bronze consists of copper 89·6 per cent. and aluminium 10·4 per cent. An iron-aluminium bronze, consisting of copper, aluminium, and iron, has been recently shown to have remarkable and desirable properties; and another recent addition is a high-tensile brass consisting of copper, zinc, aluminium, and manganese. It is clear that Birmingham and Sheffield have at their disposal an infinite variety of 'bronze' and 'brass' alloys.

Bell metal is another alloy of copper and tin; it is now usually made of about four parts of copper to one part of tin, but the proportions have varied between 2 : 1 and 10 : 1, and now a little lead or zinc is often added. London and Loughborough are other places where 'bell metal' is either alloyed or worked up.

A very well known alloy which is made and worked in large quantities in the Sheffield and Birmingham districts is 'German silver,' or 'nickel silver,' which usually consists of copper, nickel, and zinc. There is also a whole series of nickel alloys, some of which are of great use in electrical work. The making and use of these mainly non-ferrous metals offer an unlimited field for research and experiment. Many towns carry on some part of this work, but Birmingham and Sheffield are the leaders.

Some Uses of the Non-ferrous Metals

There is a large and varied industry carried on in South Wales, the Midlands, Sheffield, and, to a less extent, in the Tyne and the Mersey regions—that is, in regions where the non-ferrous metals and alloys are largely used.

South Wales makes sheets, plates, and tubes of copper and 'yellow metal'; also lead sheets and lead pipes of various kinds. A big South Wales industry is the making of tinplate. Tinplates are thin sheets of iron or steel coated with a thin

layer of tin; thus two great industries are brought together, the manufacture of steel and the smelting of tin. The ordinary tins used in the home and the tin containers in which foods are preserved are made of tinplate. The Welsh manufacture of tinplate is the most important in Europe, is 70 per cent. for export, and employs 22,000 people.

A somewhat similar process to that of tinplate manufacture is the making of 'galvanized' iron sheets; these are sheets of iron or steel which have been dipped in molten zinc and have thus received a thin coating of that metal. This is another industry which is pre-eminently a South Wales one, and employs 3500 people. The productions of one great and well-known firm which has works in South Wales and elsewhere, and which is a producer of these commodities on a large scale, may fittingly be quoted here. Its possible annual output is given by Lord Aberconway in *The Basic Industries of Great Britain* as follows:

	Tons
Pig-iron	360,000
Steel ingots and castings . . .	1,020,000
Semi-finished steel	600,000
Rails and small sections . . .	150,000
Light plates and finished plates . .	165,000
Black sheets	50,000
Tinned, galvanized, or lead-coated sheets	100,000
Tinned plates	1,500,000
Tubes	75,000

The Birmingham district is the greatest region in Britain for the working up of the varied non-ferrous metals and alloys into a thousand things used in everyday life. Birmingham itself is famous for the multiplicity and variety of its metallurgical industries, including those in which the expensive metals, silver, gold, and platinum, are used. The working up of these metals requires a high degree of skill, and is often highly paid work. To begin an enumeration of the things produced would be much like beginning a big trade catalogue. Perhaps it is all best summarized by saying that the Birmingham region can make everything in which the metals mentioned earlier in this chapter are concerned, together

with articles in which silver, gold, and platinum play a part. At the risk of seeming invidious, and of omitting far more things than are mentioned, here are a few articles and groups which illustrate the subject: brass and copper tubes, brass pins and brass paper-fasteners, copper, brass, and bronze articles for cabinet work, gas-fittings and accessories, water-fittings, steam-fittings for factories and for ships, brass bedsteads, metal ornaments of all descriptions, and finally silver, gold, and plated goods in almost bewildering variety.

Sheffield also does a great deal of work in which non-ferrous metals and their alloys are concerned; it smelts copper, brass, bronze, zinc, aluminium, silver, and gold; it makes ingots, sheets, wire, and tubes of nickel silver and other alloys. It makes, for example, copper pans, tanks, pipes, coils, etc. One Sheffield firm claims that it handled over 90 per cent. of the chief ore of the metal molybdenum that came into England in 1926. This metal is alloyed with nickel and copper, and with iron in molybdenum steel. Some of the non-ferrous alloys manufactured by the same firm are copper-tungsten, copper-titanium, copper-manganese, copper-chrome; and the same firm also supplies metallic chromium. Of course, these are only illustrations selected from a very wide field, but they show something of the work of another British region which shares this varied non-ferrous metallurgical work.

A great deal of the work now known as silver-plating, nickel-plating, and electroplating is carried on in both the Birmingham and Sheffield districts. It remains to be added, too, that there are Assay Offices at Birmingham and Sheffield which 'hall mark' the goods turned out by the goldsmiths and silversmiths of these important metal-working regions.

It was at Sheffield that the original art of silver-plating[1] was developed in the eighteenth century, and it was mainly there that the making of the highly prized 'Sheffield plate' was carried on. The possibility of coating an article made of copper with a thin layer of silver was discovered there by Thomas Bolsover in 1742. He saw the possibility of making articles which looked like silver, but which were both stronger

[1] Now generally known as electroplating.

and cheaper, and from that discovery and Bolsover's application of it the famous industry sprang up. Hancock later conceived the idea of making the silver-plated sheet first and the required article afterward, and Cadman, in 1784, introduced still further improvements. Meanwhile they had learned how to make a silver-coated ingot which was ready to be rolled into a very thin sheet. A rolling 'mill' with highly polished steel rollers had been introduced about 1760; this was able to convert the plated ingot into a sheet one-fortieth of the original thickness, in which sheet the relative thicknesses of the copper and silver were maintained. It was from these homogeneous, well-rolled sheets that most of the exquisitely beautiful articles of 'Sheffield plate'—now so highly prized by collectors, and for which such high prices are paid—were made by highly skilled workmen, usually working individually.

The discoveries of Bolsover, Hancock, and Cadman were typical 'inventions' of that wonderful period of inventions, the eighteenth century. The articles produced partly redeemed that period from the charge so often made, that the Industrial Revolution was a time of ugliness. The 'Sheffield plate' of the years 1760–1840 ranks among the highest achievements of British art. It should not, of course, be overlooked that Birmingham shared in the industry and profited by it; but 'Sheffield plate' was the name by which the articles were always known.

The process arose somewhat rapidly, flourished exceedingly for over three-quarters of a century, and then died with startling rapidity. The introduction of electroplating, from about 1837 to 1840, gave the deathblow to the old process, and the original 'Sheffield plate' passed into the domain of the collector and became only too frequently the aim of the successful forger.

CHAPTER XIII

SHIPBUILDING

The foundations of British manufacturing industry have already been likened to the three legs of a tripod, with coal, iron, and ships as the three legs upon which all the less basic industries rest. Two of these three really basic industries have been discussed, and the third must now be considered.

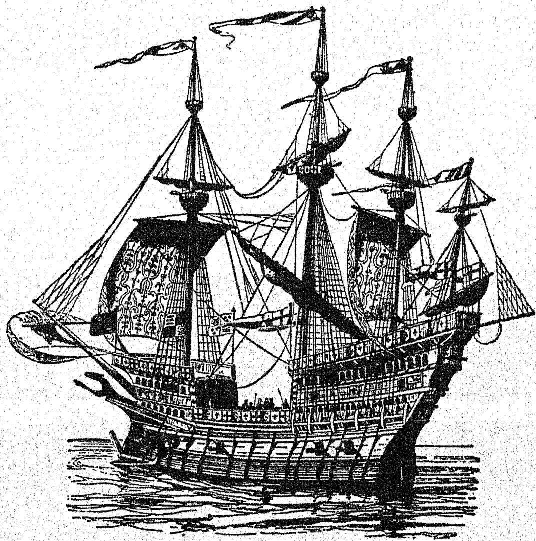
Britain's manufacturing industries are peculiarly dependent upon transport—communication with the rest of the world—because so much raw material must be brought from abroad, and such a large proportion of her manufactures must be sold abroad. Hence the supreme importance of shipping to Britain. It is no exaggeration to say that Britain's continued supremacy in industry depends very largely upon her ships and shipping facilities. If her shipping were to be neglected she would surely fall back at once into the position of a second-rate nation; and it is absolutely certain that she would not then be able to support her population of nearly 50,000,000. Three things are therefore essential to the continued success of British manufactures—first-rate ships, first-rate ports, and first-rate sailors. Britain simply cannot afford to be behind any other nation in any one of these.

A number of causes conspire to make Britain a great builder of ships: she needs them for her immense overseas trade, she has natural facilities for building and launching them, and she now has a great volume of experience to fall back upon. The study of British shipbuilding in this chapter will be treated under three headings—(i) historical, (ii) geographical distribution and location, (iii) the relative world-position of British shipping.

Historical

One of the chief justifications for giving to King Alfred the title of "the Great" is that he realized how England's

well-being demanded ships, and he built, as the *Anglo-Saxon Chronicle* records, "long ships that were full nigh twice as long as the others; some had sixty oars, some more; they were both swifter and steadier than the others." This was more than a thousand years ago. Coming down to medieval



THE "HENRY GRÂCE À DIEU"

days, the Shipman of Chaucer's *Canterbury Tales* was a man who knew his job.

> He knew wel alle the havenes, as they were,
> From Gootlond to the Cape of Fynystere,
> And every cryke in Britaigne and in Spayne.

"Gootlond" is the modern Gothland, an island in the Baltic Sea, and on its shores was the famous port of Wisby, one of the great marts of the Hanseatic League, and one of the most famous seaports of the time.

The Tudor kings paid considerable attention to shipping. Henry VII gave to John Cabot a present of £10 because he had found a "new isle," and afterward awarded him a pension of £20. His son's ship, the *Henry Grâce à Dieu* (usually

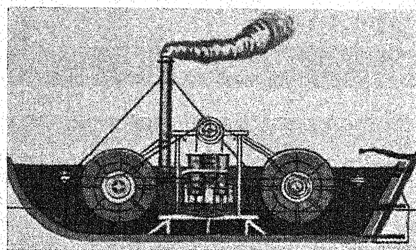
known as the *Great Harry*) was one of the wonders of the time of Henry VIII; and the same king gave a Charter to Trinity House, and so started that long series of investigations of British coasts and their tides and currents which have been of such enormous value to British shipping. He also built dockyards at Deptford, Woolwich, and Portsmouth. In Queen Elizabeth's time came the victory over the Spanish Armada, and it was largely due to the knowledge of the English seamen, who had worked out new devices in the building and handling of ships, and whose ships themselves were models of neatness and excellent workmanship.

Captain James Cook

The ships and the sailors of the time of the Napoleonic wars carried on the same British tradition. The Seven Years War, the founding of so many colonies in the eighteenth century, and the voyages of Captain James Cook all showed that the British knew the art of building and handling ships. And before the era of the "hearts of oak" was over the dawn of a new period was showing in Britain, though half a century had to pass before the steamship was as fully trusted on the ocean as the 'wooden walls' of British shipping had been.

The Beginnings of the Steamship Era in Britain. In the Andersonian Museum at Glasgow there is still preserved a small one-horse-power steamer which was built by William Symington, a lead-mine engineer, at the expense of Patrick Miller, a banker. This small structure was a double boat; the engine was on one side, the boiler on the other, and the wheel between them. It was propelled at the rate of five miles an hour on the little lake at Dalswinton, in Dumfriesshire. This was in 1788. In the following year Miller employed Symington to plan a twelve-horse-power engine, which was made by the famous Carron Iron Company; this steam-

boat drew a heavy load on the Forth and Clyde Canal at a speed of seven miles an hour. Symington made another steamboat in 1802, which drew two barges on the same canal a distance of twenty miles in six hours against a strong wind. Among those who saw this steamboat was Henry Bell, who afterward distinguished himself in connexion with steam navigation. Another important and frequent visitor to some of Symington's experiments was the famous Robert Fulton, who did much for early steam navigation in the United States. Fulton's celebrated vessel, the *Clermont*, was equipped with engines made by Boulton and Watt, and it made a voyage up the river Hudson, from New York to Albany, one hundred and fifty miles, at an average speed of five miles an hour. Fulton does not seem to have acknowledged sufficiently in his writings the ready help which Symington gave him on his many visits to Scotland.



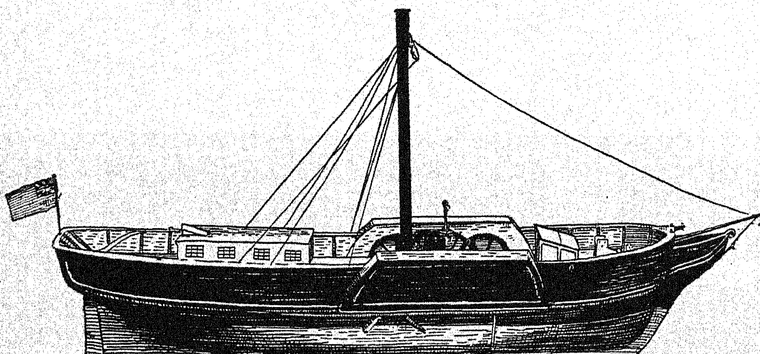
SYMINGTON'S "CHARLOTTE DUNDAS" (ABOUT 1802)

Henry Bell inspected this pioneer steamboat.

Henry Bell had known Miller, Symington, and Fulton, and had seen and learned from their only partial successes. He planned and had built to his design in 1811 a small steamer which he called the *Comet*. This little steamboat began to ply regularly between Glasgow and Helensburgh in 1812, and was probably the first steamboat in Europe to cater for regular passenger traffic. Hutchison placed his famous *Elizabeth* on the Clyde in 1813; she carried a hundred passengers at the rate of seven miles an hour. Very soon afterward a small steamer began to ply on the Severn, and another on the Thames. Progress was now so rapid that by 1820 there were over thirty steamers at work in the British Isles, and in the next year they were employed in the mail service between Holyhead and Dublin and between Dover and Calais.

The wooden vessels which made the fame of British sailors had been built on the Thames, the Tyne, the Clyde, and at Plymouth, as well as in many a smaller old-world port, such as Aberdeen, Whitby, King's Lynn, or Bideford. Glasgow and the Clyde were already marked out by the early experiments of Symington, Bell, and others for taking a big share of the new work which was destined to come with the expansion of the steamboat era.

At the end of the great wars of the Napoleonic period there were about 25,000 merchant vessels registered at ports



THE "COMET"

in the British Isles; but they were mostly small in size. There was little further progress in shipbuilding until the repeal of the Navigation Acts in 1849; by the later Acts of 1850 and 1854 the whole of the carrying trade of Great Britain and the Colonies was thrown open to ships of all nations and to ships which might have been built in colonial or foreign shipyards. The shipbuilders of Britain had thus to compete with the shipyards of the world, and they were quite naturally full of apprehension as to the future. Really, their great chance had come, and they entered upon a period of amazing prosperity and tremendous expansion. Steam-driven vessels were apparently still awaiting their opportunity. Two steamers had crossed the Atlantic in 1838, the *Sirius*, from Cork, and the *Great Western*, from Bristol;

the former was a few hours earlier in reaching New York; the latter had started three days later. These were great achievements, but as late as 1850 not more than 5 per cent. of the tonnage of the United Kingdom was under steam.

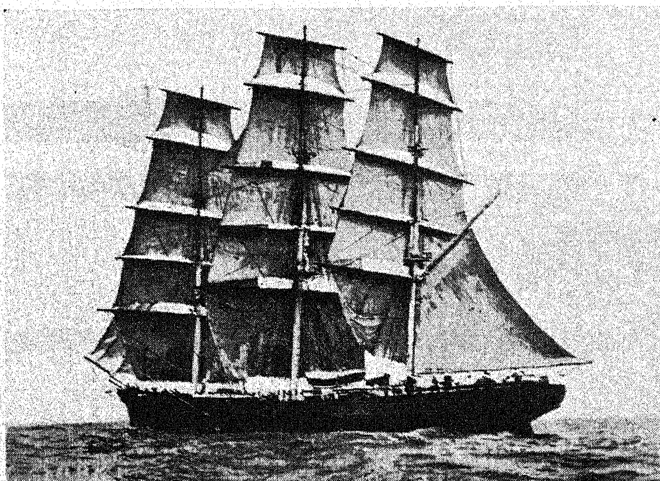
The increasing demand for shipping that developed so rapidly after 1850 gave the British shipbuilding yards their great chance, and fortunately for them the resources of the country in coal and iron were ready to help them in their new era of expansion. A new raw material was eventually to displace the timber; and Britain was far better placed than her competitors to enter upon this new phase of industry. It may be said that from 1850 onward the two new factors were (i) the use of iron and then steel, (ii) eventually the full adoption of steam.

Iron vessels were, of course, not quite new. It will be remembered that John Wilkinson, the "Iron King," had surprised the people of his day by placing his iron barge on the Severn at Broseley, in 1787. There were many iron barges on the British canals before 1820. A sea-going iron vessel was built in 1821. The above-mentioned *Sirius* was built in London, and was the first iron vessel to be entered at Lloyd's; this was in 1837. The *Great Western*, her rival in the Atlantic 'race,' was a wooden ship; but her success led the directors of the owning company to build a larger one of iron; this was the *Great Britain*, designed by the famous engineer Brunel. Her keel was laid at Bristol in 1839; she was finished in 1843, and entered the Atlantic trade in 1844. Later the *Great Britain* was reduced in length and turned into a sailing-ship. For many years she has lain as a hulk in the harbour of Port Stanley, in the Falkland Islands.

In the years 1850–70 steam tonnage increased nearly sevenfold, but sail tonnage was also increasing at the same time, though not at so great a rate relatively. In 1870 the total sail tonnage was four times the steam tonnage; by 1880 the steam tonnage was to the sail tonnage as 2:3 roughly, and after 1880 comparatively little sail tonnage was added. During the twenty-year period of 1850–70 composite ships were largely built; the framework was of iron, and there was a wooden shell with a sheath of copper. The *Cutty Sark*,

one of the fastest sailing-vessels ever built, was of this period; this ship may be seen in the Thames, where she is preserved as a famous historic relic.

There was a good deal of trouble in the mid-century due to the rapid rusting and fouling of the iron bottoms in sea-water. After the invention of the steel converter by Bessemer and the rapid cheapening of steel plates of that metal

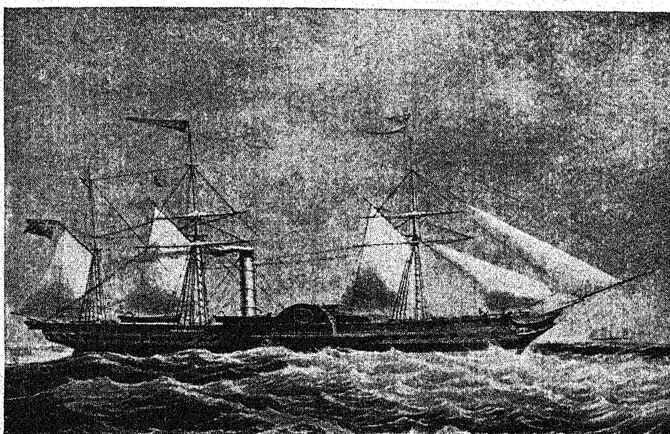


THE "CUTTY SARK"

gradually took the place of iron, and the change was more rapid still after 1877, when Lloyd's adopted rules for the building of steel ships. By 1900 iron had dropped out altogether, and the hulls of ships were built entirely of steel.

Meanwhile other changes were taking place, the most important being the rapid increase in size. The first Cunard 'liner,' built in 1840, was of 1154 gross tons; the *Persia*, launched in 1855, was the largest steamer in the world at the time; her gross tonnage was 3600 tons. The *Lusitania*, sunk by the Germans in the early days of their submarine campaign in the Great War, was of 32,000 tons. The *Normandie* is 83,000 tons, and the *Queen Mary* 81,235 tons.

The gross tonnage per passenger has risen from 9·4 in 1893 to 38·5 in one of the largest modern liners: steel has meant increase in speed as well as in size and safety. The *Britannia*, the earliest of the Cunarders, had a speed of eight and a half knots; the average speed of the great *Queen Mary*, one of the fastest liners afloat to-day, is twenty-nine knots. She won the Blue Riband for the fastest

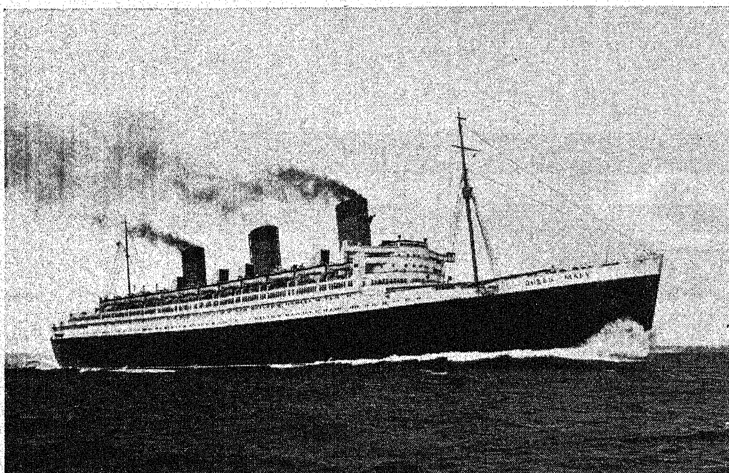


THE "CALEDONIA," ONE OF THE FIRST CUNARDERS

double crossing of the Atlantic in August 1938; the *Bremen* and the *Europa*, both German vessels, which held the record from 1929 to 1933, accomplished the single crossing in a little less than five days. Both the *Normandie* and the *Queen Mary* have reduced this time to a little less than four days.

Other great changes which have largely been brought about by British shipbuilders, and which have profoundly affected the shipping and shipbuilding industries, are connected with the boilers, the engines, and the method of driving the vessel. The older types of boilers were boxlike and had flat sides; these gave place to cylindrical steel boilers which could stand much higher steam pressures. The cylindrical boilers of the last century are now largely replaced by water-tube boilers, and pressures of over 200 pounds are quite common, instead

of the thirty pounds of the earlier days. Steel of such excellent tough quality can now be obtained that a vessel was launched on the Clyde in 1926 which had a boiler pressure of 550 pounds per square inch. The boilers of many steamships now use oil instead of coal, and this has had its reaction in the coalfields—a reaction not confined to home



THE "QUEEN MARY"
By courtesy of Cunard White Star, Ltd.

consumption either, since much of the coal previously exported was for bunker purposes. Diesel oil-engines, which can use heavier and much cheaper oils, are now introducing a further economy in the cost of driving steamships, and are making it more difficult for the coal-producers to recover their lost trade in supplying ships with fuel. The reader should be warned, however, against the prevalent idea that ships now demand very little coal. Of the world tonnage launched in 1937, steamers fitted for burning oil fuel formed 17 per cent.; those fitted with turbines represented 57 per cent. The steamship driven by steam derived from the burning of coal is not yet a thing of the past; and much work is now being done in the way of testing whether finely

pulverized coal, or coal treated in any other way, can recover some of the lost ground.

In connexion with the method of propelling the ship, as well as with the form of energy used, there have been great changes. From the 'paddle steamer' of the early days to the screw-driven steamboat was a great change, both in efficiency and in the comfort of the passengers. At the turn of the century, the steam-turbine, invented by Parsons, on Tyneside, added another victory to high-speed traffic, and practically every vessel built for a speed of twenty knots and upward is now equipped with geared turbine engines, which represent yet another advance.

Other changes in shipbuilding connected with the efficiency of shipping have been the development of refrigerating plants and chambers for the transport across the ocean of meat, fruit, and dairy produce. The first cargo of frozen meat was brought from Australia to England in 1879. Since that time the carrying of fruit from the West Indies, Central America, South Africa, and Australia has been greatly developed; the first cargo of fruit from Jamaica brought to England in freezing chambers came in 1896. Immense quantities of dairy produce are now brought to Britain in refrigerating chambers; the first large cargo came from Australia in 1911. Now eggs and butter from New Zealand, Australia, Canada, China, and Egypt are regular imports into Britain.

Oil-tankers have largely replaced the old method of carrying petroleum across the ocean in tins and barrels. The first of these vessels was built in 1886, and had a capacity of 5000 tons of oil, which would be equal to nearly 1,500,000 gallons. Another similar development in shipbuilding which has largely modified special phases of the industry has been the making of specially designed vessels to carry in bulk such cargoes of wheat, oats, maize, iron ore, nitrates, coal, and coke. It is this attention to size and capacity, adaptation to special needs, development of greater speed, and economy in production which has kept the British industry of shipbuilding in front of that of any other nation, except for the one year at the end of the Great War, when the United States

of America took first place. This subject will be mentioned again later.

Geographical Distribution and Location

A great change has come over the distribution of the British shipbuilding industry since the early days of what may be

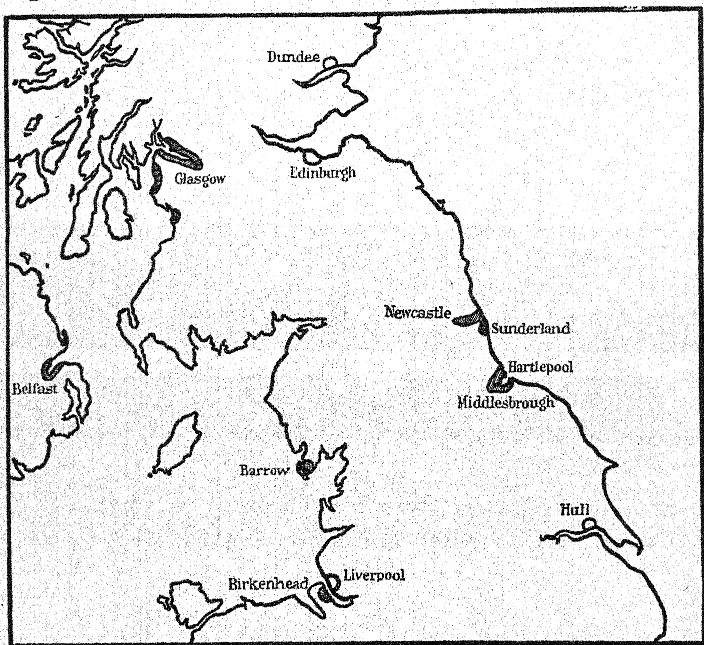


Fig. 17. The Chief Shipbuilding Centres in Britain
Compare with Figs. 13, 14, and 15.

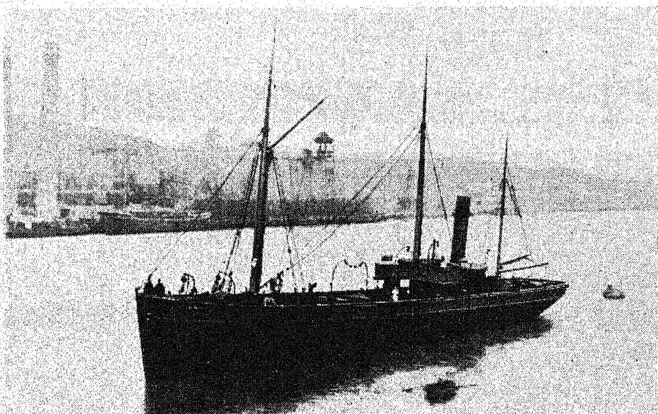
called the recent period—that is, the period since the great expansion began, after 1850. The banks of the river Thames, chiefly below London Bridge, once formed the greatest shipbuilding district in the world. There were also some well-known firms above London Bridge—for example, the famous Thornycroft's at Chiswick, a name so well known to-day in connexion with the University boat-race. This firm, which

started at Chiswick in 1866, has long since migrated to Southampton. Many famous yards existed, and many famous and important ships were built on the Thames below London Bridge. One of the best-known yards was that at Blackwall, which dated back to the early seventeenth century; the Orient Line of steamers was cradled there. A well-known firm was the Thames Iron-works and Shipbuilding Company, which had its works at Canning Town; this firm built the first British ironclad, the *Warrior*, in 1859; the battleship *Thunderer*, completed in 1911, was the last of its class built by them. Now the company has vanished. The historic yard at Millwall was closed in 1852, but Scott Russell took it over afterward for the building of the *Great Eastern*, the wonder-ship of the middle of the century, designed by the great engineer Brunel. This famous ship never made good in the North Atlantic service as a passenger ship, but she was successfully used for the laying of submarine telegraph cables at the bottom of the Atlantic. The launching weight of this great vessel was 12,000 tons; the weight when loaded with passengers and cargo was 30,000 tons. A book of 1867, when she was still famous, describes the *Great Eastern* as "the grandest ship in the world." Now the Thames shipbuilding has practically all gone, and all that is left is repairing work and the building of some specialities, such as torpedo-boats, etc.

The heavy cost in rent, rates, and taxes, the greater cost of labour, and the cost of carriage of the iron and steel plates and other materials proved too great. The iron plates of the *Great Eastern*, for example, were rolled at Rotherham. Very probably the difficulty of launching large vessels was a factor also; the historic failure in the attempted launching of the *Great Eastern* was a case in point. It cost £60,000 in labour and materials to complete the launching of that great vessel. But it was general economic conditions that finally determined the great migration. It was cheaper to use coal, iron, steel, and other metals and alloys nearer the place where they were produced than to bring them 200 miles by sea or rail to Thames-side.

All the *great* shipbuilding yards are now found in the North

Country; with the exception of the one at Birkenhead they are all north of latitude 54° N. Twenty-six great shipbuilding yards appear in the lists of those firms which built over 40,000 tons in the two years 1927 and 1928. Twenty-five of these are in the two main regions, the North-east of England (including Tyne, Wear, and Tees) and the Clyde. It is not far wrong to say that these two regions build from 85 to 90 per cent. of British merchant shipping, and that

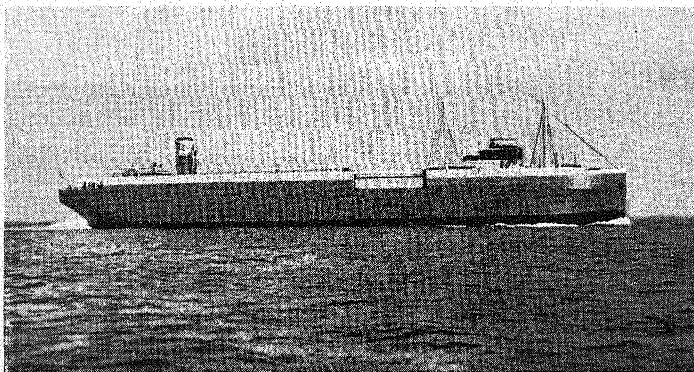


THE "JOHN BOWES"

they divide that amount almost equally. There is considerable and sometimes rather keen rivalry between the advocates of the two regions, but no great injustice is done by supposing that they are very near to being equal in importance. In 1936 the tonnage of merchant vessels of over 100 tons launched in the United Kingdom was 856,000, of which 40 per cent. was constructed on the north-east coast, and 33 per cent. in the Clyde region. The amount of tonnage launched in 1929 was considerably higher—viz., 1,522,673—and the north-eastern area had a greater share than at present. According to the *River Tyne Official Handbook*, in 1925 there were nine shipbuilding yards on the north side of the Tyne and eleven on the south side, with a total of 115 'slips' for

the launching of ships. In the year 1924 there were sixty-four vessels launched from that river, with a total net registered tonnage of 152,165 tons. The years 1911 and 1913 were the peak years of Tyne shipbuilding; the net tonnage of those years was 242,276 tons (1911) and 238,034 tons (1913).

The Tyne is an old shipbuilding region. Defoe wrote in his day that "They build ships here to perfection, I mean as to strength, and firmness, and to bear the sea." Iron ships were



"SEATRAIN"

By courtesy of Messrs Swan, Hunter and Wigham Richardson, Ltd.

Photo Frank and Sons

built as early as the forties, but it was the building of the first screw collier, *John Bowes*,[1] in 1852, that finally established the Tyne as a great centre for iron ships. The transition from iron to steel in the seventies and eighties was comparatively easy, because the region is so near the great steel-works of Durham and North-east Yorkshire. The great *Mauretania*, long the fastest steamer afloat, and the battleship *Nelson* are among the modern triumphs of the Tyne. The largest floating-docks the world has seen have been made on the Tyne. The new floating-dock at Singapore has been constructed and erected by the well-known Wallsend ship-

[1] The vessel was built by Charles M. Palmer, afterward Sir Charles Mark Palmer.

builders. This is the largest structure which has crossed the Indian Ocean, and it is one of the Tyne's greatest triumphs in the realms of marine-engineering construction. Almost at the end of 1928 there was sent out from the same yard the new steam ferry-boat *Seatrain*, improved on in 1932 by the American-built *Seatrain New York* and *Seatrain Havana* in the New Orleans-Havana service.

The Clyde came into prominence in the very early days of modern shipbuilding. After the successes of Bell and Hutchison in 1812–13 the challenge to the development of shipbuilding was obvious, and Robert Napier founded his famous firm in 1823. The development has been so great that there are now no less than forty shipbuilding firms on the banks of the Clyde; there are, in addition, twenty builders of marine boilers and engines who are not shipbuilders. Between Broomielaw Bridge, in Glasgow itself, and Greenock there is a twenty-mile stretch of river largely given over to shipbuilding, repairing, and equipment; and this very famous, vigorous, and enterprising region has within the last fifty years built more ships and more tonnage than any other river in the world. In the year 1913 the output of ships reached the enormous total of over 750,000 tons; this was the summit year of normal times. It is estimated that the Clyde shipyards could turn out over a million tons of new shipping in a year; but the demand for new vessels seems to vary from about one-third to one-half of that quantity. Many very well known ships have come from the Clyde shipyards; the ill-fated *Lusitania*, which was sunk in 1915, and the gigantic *Queen Mary* are two modern examples.

It is not difficult to understand the advantages possessed by the two great shipbuilding regions; iron- and steel-works of various kinds are near at hand, and marine engineering is a sort of connecter between the iron- and steel-works and the shipbuilding industry. It is on this account that busy shipyards are generally a sign of prosperity in the iron and steel trades and engineering. The industries react on each other in a very close and intimate fashion. The presence of coal is an important factor too. Both rivers have been widened and deepened, and every facility for the launching

of ships has been provided. The incidentals of ships, such as winches, electrical gear, refrigerating plant, apparatus for the distillation of water, and numerous other things metallurgical must be at hand. The building of marine engines forms, of course, one of the greatest ancillary industries of these regions. In the region including the Tyne, Wear, and Tees there are twenty-two marine-engine engineering firms, and nine of these are in the list of "The Largest Marine-engine Builders" as given in *Whitaker's Almanack* for 1930. Eight others of these largest firms are on the Clyde, and the rest are at Barrow-in-Furness, Belfast, Birkenhead, and Southampton. The last-named places, except Southampton, are the other chief shipbuilding centres in addition to the Clyde and the North-east of England.

These three other shipbuilding centres usually share between them from 10 per cent. to 15 per cent. of the output of merchant tonnage of the United Kingdom, Belfast taking first place. Here, on the banks of the Lagan, are two great and well-known shipbuilding yards. That owned by the famous firm of Harland and Wolff is said to be the largest in the world, and covers 220 acres. This company was first in the list of the largest shipbuilders of 1927–28, as given in *Whitaker's Almanack*, and it stood fourth in the total horse-power of marine engines in the same two years. Harland and Wolff also own shipbuilding yards on the Clyde, and control ship-repairing yards at Liverpool, London, and Southampton. The groups of workshops and yards under the Port of London Authority, on the Thames, are also among those managed by this firm. The other Belfast firm is that of Workman, Clark, whose output in gross tonnage in 1927–28 was about one-fourth of that of Harland and Wolff.

The great shipbuilding yard at Birkenhead is closely associated in finance and management with steel-works in West Yorkshire; it turned out 101,238 gross tonnage of ships in 1927–28. The Barrow shipbuilding yard of Vickers, Ltd., is a branch of the activities of that great firm; it turned out 57,559 gross tonnage in 1927–28, and stood seventh in the list of marine-engine builders as given in *Whitaker's Almanack* for the same years. This result is partly a consequence of

the establishment of the famous steel-works of Barrow and district, where first the Bessemer process and later the Siemens-Martin open-hearth process have been in vogue. The steel-making industry, in its turn, has been associated with the rich deposits of hæmatite ore (free from phosphorus) found in Furness and neighbourhood.

The Relative World-position of British Shipbuilding

It is evident that the United Kingdom cannot afford to fall behind in the race for supremacy in shipbuilding. Considering merchant vessels only, the United Kingdom launched in each year before the Great War a greater gross tonnage than all the rest of the world added together. This remarkable supremacy ended after 1913, and in only five years since then has the output of the United Kingdom been greater than that of the rest of the world; these years were 1924, 1927, 1928, 1929, and 1930.

While it is essential that Britain should hold a high position, and while it is hoped that she will long be first among the nations, it does not seem likely that she will continue to beat the combined output of the rest of the world. The retention of her high position obviously depends in large measure upon the efficiency of her shipbuilding yards, and this includes many factors, the chief being the efficiency and ability of management, the effectiveness and relative cheapness of labour, and the cost of raw materials. A departmental committee appointed by the Board of Trade to report on shipbuilding and marine engineering said in 1917 that "many of the yards and engine works are admirably equipped with modern machinery and are managed with the greatest ability." The directions in which care should be exercised, if Britain is to retain her position, are in the increased use of improved mechanical appliances, the full adoption of labour-saving machine-tools, the increased standardization of ships' parts, and especially keen research dealing with new materials, possible new methods of construction, and the changing needs of shipowners. That the British shipbuilders

seem to be living up to those suggestions is borne out by the reports of the building and launching of the *Viceroy of India*, a new P. and O. mail-steamer, in September 1928. She was the first large passenger steamer to be fitted with high-pressure steam and turbo-electric propulsion. The improvements make for economy in the use of fuel, lessen the vibration of the ship, and make much less noise than the geared turbines. The reader will no doubt notice the progress in the method of propulsion within the last thirty years—first steam-turbines, then geared steam-turbines, and now turbo-electric propulsion.

The following table shows the relative position in shipping of Great Britain and Ireland compared with the rest of the world for the years 1914 and 1937:

Country	Gross tonnage for June 1914	Gross tonnage for June 1937
Great Britain and Ireland	18,892,000	17,544,000
British Dominions	1,632,000	3,085,000
United States of America	4,287,000	12,337,000
Germany	5,135,000	3,937,000
Japan	1,708,000	4,475,000
France	1,922,000	2,870,000
Norway	1,957,000	4,348,000
Other countries	11,828,000	17,690,000
World total	47,361,000	66,286,000

The following points may be mentioned in mitigation of the apparent tendency toward a fall in the British share of world shipbuilding: firstly, other nations are becoming more ambitious to build for themselves, and competition is becoming keener; secondly, vessels have become bigger, and generally speed has increased, so that more passengers and goods can be carried in a given time. It is perhaps no wonder that for many years the number of insured work-people of the shipbuilding industry unemployed in the Clyde region has been from 20,000 to 25,000, or over 30 per cent.

In respect of actual gross tonnage of vessels (steam and

motor), as recorded in *Whitaker's Almanack* for 1939, the United Kingdom possessed 26·2 per cent. of the world's shipping, the British Empire 30·9 per cent. The United States of America comes next, with 17·6 per cent., which figure includes her shipping on the Great Lakes and in the Philippines. It will be noticed that the British Empire and the United States together own 48·5 per cent. of the shipping of the world. Japan, Norway, Germany, Italy, and France come next, in that order, each of them owning in the neighbourhood of 4–7 per cent. of the world's total. The reader may expect from these facts, and from the position of the United Kingdom as a shipbuilder, that she builds almost the whole of her own shipping, and also builds largely for other nations. These conclusions are sound. Seldom do British shipowners place their orders with foreign shipbuilders; generally speaking, this happens only under very exceptional circumstances, such as for a very unusual type of vessel or in times of labour troubles in the home yards, as in 1926. The prosperity of the shipbuilding industry in the United Kingdom demands, however, that orders for shipping be obtained from abroad. This can only be done if the British shipbuilders can render efficient service at a minimum of cost.

The great depression of 1931–33 was quickly reflected by conditions in the shipping industry, which has been called the barometer of national prosperity. The same period saw the end of the post-War boom, during which the yards had been working at full capacity in order to replace the shipping that had been destroyed. These and other factors combined to produce a crisis in the shipping industry from which it has not yet recovered. Numerous small yards have been closed for the good of the trade as a whole.

SECTION B

SOME SEMI-BASIC INDUSTRIES

CHAPTER XIV

THE CHEMICAL INDUSTRIES: THE HEAVY CHEMICALS

THE chemical industries have come to play such an important part in the life of a modern industrial people that they may fairly be regarded as semi-basic. Whole groups of other industries are continually indebted to one or other of the common things produced by the chemical manufacturer. Even the most fundamental industry of all—that is, farming, agriculture in the widest sense—becomes more and more dependent upon the chemical industries as it becomes more necessary that the land should yield more food. In home life too chemicals play an ever-increasing part, in making the house beautiful, in keeping it clean, in the laundry work of the home or in the business laundry, as disinfectants and medicines, in the bathroom, in connexion with the toilet, and, in fact, in almost every phase of modern life.

THE HEAVY CHEMICALS

Under this head are included a number of common chemicals which are made on a big scale and which play a fundamental part in many other very important industries. It will serve the purpose of the present review if four groups are considered. These groups are the common mineral acids, sulphuric, hydrochloric, and nitric; the common alkalis, caustic soda, soda ash, soda crystals, and the corresponding potash compounds; the common bleaching chemicals, chlorine, bleaching-powder, and the common bleaching liquids; ammonia and the ammonia compounds. These well-known

chemicals are fundamental and of very great importance. No attempt can be made here to describe the manufacture of them in the language of the technical chemist; all that can be attempted is an all-round review that indicates generally the places or districts where they are made, the chief reasons for that localization, and some mention of the part they play in common life and in other industries. It should be clearly understood that they are selected as probably the most important out of a long list of heavy chemicals.

The Common Mineral Acids. The brief study of these will centre round *sulphuric acid*, not only because of its own great importance, but also because the others may be made by means of it, though they are not always so made.

It was once suggested by an enthusiastic chemist, and was taken up by keen politicians at the time, that the amount of sulphuric acid used by a nation may be regarded as a measure of its advancement in civilization. That would be written down by many people as a biased claim, although it was widely quoted before the Great War, but there is no exaggeration in the statement that many phases of modern life in a country such as Britain would soon be put to a serious pass if the manufacture of sulphuric acid were forbidden. It is even yet the life-blood of the chemical industry in general, and there can be few branches of British industry into which the influence of the acid itself or its immediate products does not penetrate.

A vast amount of sulphuric acid is made in Britain; in 1936 and 1937 it was about a million tons per annum, which works out at nearly forty-five pounds per head. As a recent writer has pointed out, this is more by weight than the amount of sugar used per head! The amount seems on the decline, owing to new processes, which dispense with its use.

The manufacture of sulphuric acid is fairly widespread in the British Isles, as may be expected, but it is definitely located in or near the great centres of population or close to the other great industries which are its natural markets. The Mersey and Irwell region, from Liverpool to the east of Manchester, makes enormous quantities; North-east Lancashire follows at a great distance. The West Riding of York-

shire has sulphuric-acid works at Leeds, Bradford, near Huddersfield, and Dewsbury. East and South-east London is another district. Oldbury, near Birmingham, Avonmouth, Swansea, Seaton Carew (Hartlepool), Middlesbrough, Maryport, Irvine (Ayrshire), and Aberdeen are other places where sulphuric-acid works exist.

By far the greatest use of sulphuric acid is in the manufacture of superphosphate, ammonium sulphate, and potassium sulphate, all very important 'artificial manures,' which are widely used. It is estimated that 6,000,000 tons of sulphuric acid per annum are used in the manufacture of superphosphate of lime alone, or about 40 per cent. of the world's output of the acid. A very large quantity of sulphuric acid goes to gas-works and coke-oven recovery plants, to combine with the ammonia which is there being 'recovered'; the familiar ammonium sulphate is thus formed.

Much sulphuric acid is still used in the production of 'salt cake' by the action of the acid on common salt. Salt cake is very widely used in glass manufacture. The familiar hydrochloric acid is a by-product in the salt-cake process; but hydrochloric acid can now be made, by another method, more directly from common salt.

Nitric acid was formerly made almost exclusively by acting upon saltpetre or Chile 'saltpetre' with strong sulphuric acid, a method which is still in use, but nitric acid can now be made indirectly from the nitrogen of the atmosphere.

Sulphuric acid is also used in the manufacture of many dyestuffs, in making many fine chemicals and explosives, in the bleaching and dyeing of textiles, in the purification of petroleum, and in the pickling of steel plates before immersion in the bath of metallic tin. It is still the leading heavy chemical, although, owing, perhaps, to high prices, alternative methods have been discovered in some manufactures where the acid was once considered essential.

The Common Alkalis. The manufacture of alkalis, like that of sulphuric acid, or oil of vitriol, is an old-established industry in Britain. The manufacture of sulphuric acid seems to have commenced at Twickenham in the year 1740; the first alkali-works were set up at Walker-on-Tyne in the year 1796.

There is little alkali manufacture in or near London to-day; but an important works exists at Wallsend, on the Tyne.

Common salt is the starting-point in the alkali industry, and from it, by a roundabout process, soda ash and soda crystals have been made on a tremendous scale for more than a century. But the old complex process is not carried through to-day; only the first part of it, the making of salt cake, survives.

In the old days soda ash was the chief product, and caustic soda was made from that by the action of slaked lime. Now, by the electrolysis of brine, caustic soda is a first product, and sodium carbonate (soda ash) is made by another simple process.

The alkali manufacture of Britain illustrates very well the thesis that the location of a special industry is largely determined by four chief factors—the presence or easy import of raw materials, cheap and ready fuel and power, means of transport, and ready access to markets. The Mersey region, north and south of that important river, is the greatest region in the world for the manufacture of the alkalis; the chief works of the great firms of Brunner, Mond, and Company and the United Alkali Company (now united in Imperial Chemical Industries) are both in that region. Common salt is the chief primary raw material, and the richest British deposits of rock salt are in the Trias of Cheshire; these deposits are supplemented by the salt deposits near Fleetwood, in North Lancashire. The South Lancashire Coalfield is quite close at hand, and the coalfields of North Staffordshire and North Wales are not far away. Means of transport have always received attention from the very earliest days of modern industry. The Mersey and Irwell Navigation, the Sankey Canal, the Worsley Canal, the Bridgewater Canal, the Grand Trunk Canal, the Shropshire Union Canal, and the Weaver Navigation were all early developments of water-transport. The Liverpool and Manchester Railway, opened in 1830, really began the great era of railway development, and in the first twenty years of that era South Lancashire and North Cheshire were both well supplied with railways. The Mersey estuary has proved singularly adaptable to the grow-

ing needs of a great industrial district, and it is significant that the Manchester Ship Canal—which still stands unique—should pass through the heart of the region of alkali manufacture and its cognate and subsidiary industries. The fourth

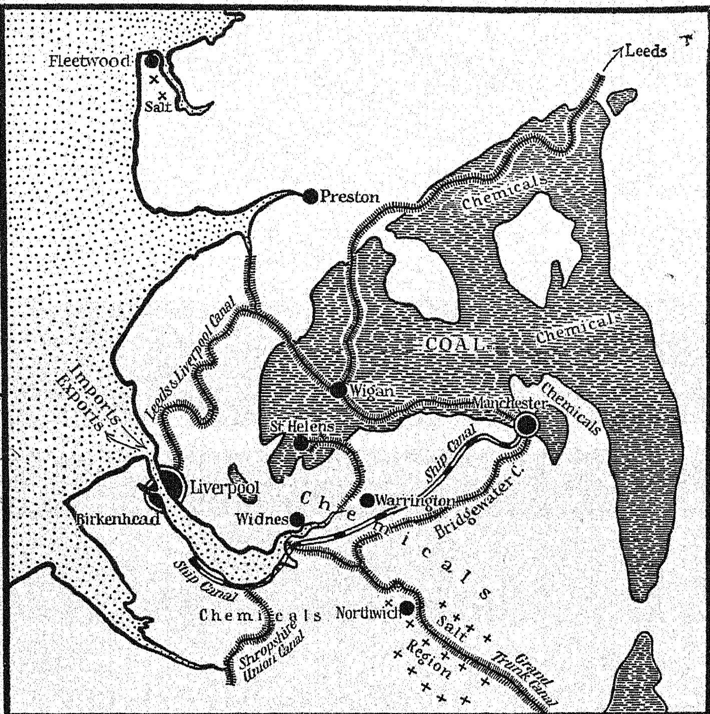


FIG. 18. DIAGRAM MAP OF THE GREAT CHEMICAL REGION OF THE MERSEY AND SOUTH LANCASHIRE

N.B.—Grand Trunk is the old and well-known name for the Trent and Mersey Canal.

factor quoted above is access to markets. Here again the Mersey region is remarkably well situated; it is close to the most densely peopled industrial region in the world; the industries of that region require large quantities of the alkalis to carry on some of their most important processes, and there have developed, close at hand, and almost in its very

midst, the greatest facilities the world knows for the export of industrial productions.

Other regions where the alkali manufacture is carried on are North-west Lancashire, South Staffordshire, Tyneside, Irvine, in Ayrshire, and Glasgow.

Common salt, or sodium chloride, the primary raw material in these alkali manufactures, is a compound of the two elements sodium and chlorine; the alkalis contain the metallic element—that is, they are compounds of sodium (or of the analogous metal potassium). There is a whole series of sodium compounds, of which caustic soda, soda ash, soda crystals, sodium bicarbonate, silicate of soda, sodium sulphide, sodium sulphate, or salt cake, sodium bisulphite, and sodium hyposulphite all play their parts in other industries. A few illustrations of their application will be appropriate at this point.

Caustic soda finds its greatest use in soap manufacture; and soap is so important that a separate section is given to it later. Caustic soda is also indispensable as a scouring and cleaning agent in the textile industries—for example, in the scouring of greasy wool before it goes to be carded or combed. It is also used in the mercerization of cotton, that process which gives to cotton treated by caustic soda something of the lustre and feel of silk. Another important use for caustic soda is in one of the standard processes for the preparation of wood-pulp for paper manufacture; and a somewhat analogous use is that in the preparation of spruce-wood pulp for the 'viscose' process of artificial-silk manufacture. This particular process is now the leading one in the production of artificial silk. There are many other industrial uses for caustic soda, but the above examples will show the reader how considerable are its contributions to the success of some important manufactures.

Soda ash and *soda crystals* (common washing-soda) find many applications in the industries and in the home. Soda ash is simply powdered sodium carbonate; washing-soda is sodium carbonate combined with a large proportion of water of crystallization. Practically all the common 'soap powders' consist of powdered hard soap mixed with a proportion of soda ash, and sometimes borax.

Sodium silicate is another of the alkali compounds which finds its way into many phases of everyday life. Its best-known use is in the familiar solution or mixture known as water-glass, used in the preservation of eggs, but measured by the amount used this is one of the least important of its applications. Sodium silicate is widely employed in soap manufacture, in the making of paper-board, in the sizing of ordinary paper, in place of animal and vegetable glues, in acid-proof cement manufacture, in concrete floors, in pottery-making, and in the making of many paints. This particular alkali is one of the most promising of the group, and its use is continually being extended.

Chlorine, Bleaching-powder, and the Hypochlorites. Chlorine is one of the chemical elements present in sodium chloride, or common salt, and it is obtained from that substance both directly and indirectly. In the old process for the manufacture of soda salt was heated with sulphuric acid, hydrochloric-acid gas was given off, and salt cake was left. This part of the old soda process is still carried on, because there is a widespread demand for the salt cake; hence hydrochloric acid is still available as a by-product. From hydrochloric-acid solution chlorine may be readily obtained by heating with manganese peroxide.

Chlorine is now obtained directly by the electrolysis of brine, or solution of salt, as well as from hydrochloric acid. The electro-chemical industry of mid-Cheshire and round Widnes now produces large quantities of the greenish-yellow gas, which is in such great demand as a bleaching agent.

Cylinders of the liquefied gas may now be purchased, and quite frequently chlorine is obtained from these cylinders and allowed to pass as a gas straight into the bleaching operation. It was the gas chlorine which the Germans liberated from cylinders at Ypres in 1915, when they commenced their poison-gas campaign. The British and their allies were reluctantly compelled to follow suit, and it was the chemical industry of the Mersey region which furnished most of the cylinders of liquid chlorine which were used by the Western Powers in that hated form of warfare which had been forced upon them.

Roughly half the chlorine gas which is made by the British works to-day is used in the manufacture of the well-known article bleaching-powder. This substance is used in enormous quantities in the bleaching of cotton and linen yarns and fabrics. Another method of using chlorine industrially now very common is to absorb the chlorine gas in a well-cooled dilute solution of caustic soda. In this way bleaching liquids are made which bear such names as 'Chloros' and 'Chlorazone'; these liquids are used extensively in the home, the school, and in other places where people congregate, as well as in some forms of industry.

Bleaching-powder and the liquids mentioned above are very often used as cheap and effective disinfectants. Especially have they been found useful and dependable in the purification of drinking water. Disease-carrying organisms are destroyed by very small additions of chlorine, and it is reported that most of the drinking water supplied to London is now treated in that way.

Ammonia. The fourth substance selected as illustrative of the heavy chemical industries is ammonia. Most of the ammonia of commerce is obtained as a by-product from three closely allied industrial processes—the manufacture of coal-gas, the production of coke for use in blast-furnaces, and the dry distillation of shale. The ammonia is trapped by causing the gases produced in these operations to pass through scrubbers, where it is absorbed in water. Ammonia is a gas; the ammonia of commerce is the gas dissolved in water. The ammonia of the gas-works and other works is caused to combine with sulphuric acid, when sulphate of ammonia crystallizes out as a white solid.

Sulphate of ammonia is used as an artificial manure or fertilizer, the object being to supply nitrogen to the plants in a form which they can assimilate. The purpose of artificial manuring is to supply the trio of plant requirements—nitrogen, potash, phosphate—in soluble form. Sulphate of ammonia is the form in which the necessary nitrogen is given to the soil, and not far short of half a million tons are sometimes produced in a year by the works mentioned, mainly for manurial purposes.

Ammonia solution is widely used in cleansing liquids in the home; and other ammonium salts are of importance. For example, sal-ammoniac, or ammonium chloride, is used in electric batteries; ammonium carbonate forms the basis of smelling-salts, and is also used in the baking industry. Ammonium nitrate is used in the production of many important dyes; and other ammonium compounds are used in medicine.

Synthetic ammonia can now be made by causing hydrogen to combine with the nitrogen from the air at very high pressures, and at a temperature of about 500° C. The process was largely developed in Germany during the War, when that country was experiencing a shortage of imported nitrates. The same process is now carried on in England at Billingham-on-Tees, by I.C.I. (Fertilizer and Synthetic Products), Ltd., a subsidiary of Imperial Chemical Industries, Ltd.

It is scarcely necessary to say that the ammonia thus produced has all the same properties as the ammonia obtained from the distillation processes, and forms exactly the same compounds with sulphuric and hydrochloric acids.

The object of the brief account in this chapter has been to show what an important part these heavy chemicals of British production play in ordinary life and in other industries. It should be remembered, too, that there is a very considerable export of these heavy chemicals. Britain occupies a high position among exporting countries in respect of exports of chemicals of all kinds, being next after Germany and the United States of America. The disturbing feature in this connexion is that Great Britain is not gaining ground. The total value of her exports in 1929 was approximately 22 per cent. greater than in 1913, which is by no means commensurate with the rise in prices. In the same period the increase in value of the total exports of the world was approximately 40 per cent., so that Great Britain clearly is not holding her own in this branch of her industries.

CHAPTER XV

COAL-TAR CHEMICALS

COAL-TAR is such an important raw material, and the chemicals derived from it are so many and so important, that the subjects merit a chapter to themselves. At first coal-tar was simply a nuisance, and the problem of disposing of it worried coal-gas engineers not a little. In the early days it was often boiled down in open pans until it was of the right consistency for the manufacture of roofing felt, and the volatile substances were allowed to escape. Later the same boiling down was done in closed vessels, and the volatile substances were condensed and used as cheap substitutes for turpentine. John Bethell, in 1838–40, used the heavy oil distilled from coal-tar for the preservation of timber, and this opened up a new era. Coal-tar was no longer a waste product.

From about 1840 to 1860 developments in the coal-tar industry followed one another in rapid succession, both the discoveries of compounds which could be obtained from coal-tar and improvements in the technique of the operations employed. Among the many discoveries of that period may be mentioned Mansfield's process for the manufacture of nitrobenzene from benzene, which latter was known to be obtainable from coal-tar. This was in 1847. In 1856 W. H. Perkin made the first coal-tar dye from impure aniline, and called it mauve; this discovery opened up a further new era, and from that time onward coal-tar was recognized as capable of furnishing a wonderful series of raw materials from which a great new chemistry could be built up.

In those earlier years coal-tar was derived almost exclusively from coal-gas manufacture, but in the latter part of the nineteenth century by-product coke ovens began to replace the older beehive ovens, and thus an additional source of coal-tar was provided.

COAL-TAR CHEMICALS

It will be remembered from what was said in an earlier chapter that the carbonization of coal is now being tried at lower temperatures than formerly, and that the products are different. The coal-tar differs in composition. Put very generally, that obtained from the horizontal gas retorts and coke ovens in which the carbonization is carried on at high temperatures—up to 1500° C.—contains from 50 per cent. to 60 per cent. of pitch, a good deal of naphthalene, and a not very large amount of tar acids, which are, however, rich in real carbolic acid; the light oils too are almost all of the benzene or aromatic group of bodies, and poor in paraffins. The tar obtained from low-temperature carbonization—from 500° to 600° C.—is different; it gives much less pitch, not much naphthalene, a larger quantity of the tar acids; and the light oils contain more paraffins and less of the benzene series.

It will be seen from this that statements about the distillation of coal-tar must be interpreted very broadly; that distillation gives, on the whole, certain definite fractions, which may be taken as the starting-points of the later descriptions. The main products may be thus stated: ammonia water, light oil, carbolic oil, creosote oil, anthracene oil, and pitch. Each of the last five yields important compounds on redistillation. Ammonia water may be dismissed at once, as containing probably only a fraction of the ammonia which has escaped condensation in the original distillation of the coal.

The relations of the other fractions must be now considered, not from a technical point of view so much as from their relation to the needs of other industries, and to the production of other substances. The lowest boiling fraction is the light oil, different in its composition according to the temperature at which the original coal was carbonized. The light oil consists very largely of hydrocarbons, and it is to this fraction that British industry must look for fuel and power oils with which to replace or supplement the petroleum oils now used on such a great scale.

From this light-oil fraction many important chemical processes start out; one of the most important is the aniline-dye

industry, which starts from benzene, the simplest of the aromatic hydrocarbons obtainable from the light oil. From toluene, another of the constituents, the famous tri-nitro-toluene, T.N.T., is made. From toluene, by a series of complex processes, the well-known sweetening compound saccharin is made; and toluene can also be regarded as a starting-point for one method of manufacture of artificial indigo.

Carbolic oil, the next higher boiling-point fraction, also yields a number of useful substances. One of the most important of these is phenol, or so-called carbolic acid, which is not only of very great importance as a disinfectant, but as the starting-point for other substances, such as salicylic acid and its series of medicinal derivatives. Phenol is also the starting-point for the manufacture of melinite and lyddite, two very powerful explosives.

Along with phenol, in the carbolic oil, are the well-known and powerful disinfectants the three cresols, which are present in many of the cheaper coal-tar disinfectants now on the market. Phenol and the cresols are also used as the starting-points for an important series of dyes.

Creosote oil is the next fraction, of still higher boiling-point. This oil is often used without further distillation for the preservation of railway sleepers, telegraph-poles, pit-props, garden fencing, etc. For the latter purposes it is put on simply as a paint, and there are now several special preparations which are sold under proprietary names and which may be used for the same purpose.

When the creosote oil is first distilled and the distillate allowed to stand there crystallizes out the solid substance called naphthalene; this is used extensively as a disinfectant and as an insecticide. In the form of moth-balls it is used to protect furs and clothing from the attacks of moths. Naphthalene is also a starting-point for the manufacture of artificial indigo, and for an important series of dyes, including naphthalene black, jet black, Manchester yellow, and diamine sky blue, to mention only a few.

The next fraction is the anthracene oil, a yellowish-green viscid liquid, from which a purified, solid anthracene is pre-

pared. This is the basis of a very important series of dyes called the alizarin dyes, and another series called the anthracene dyes. The oil which is pressed out in purifying anthracene is an ingredient of certain sheep-dips and disinfectants.

Coal-tar pitch is left in the stills after the above fractions have been distilled off in turns. It is a black, glossy substance, somewhat brittle, as a rule. Every reader must have seen it being used for road-making, for which purpose it is usually mixed with a proportion of creosote oil. An important usage of pitch is in the manufacture of coal briquettes, an industry which is carried on in the west of Glamorganshire and the adjoining part of Carmarthenshire. To make these briquettes finely divided coal, often that which would otherwise be wasted, is mixed with about 10 per cent. of pitch, and the mixture is compressed.

The reader will readily see from the above that the coal-tar chemical industry touches the everyday life and the industrial activities of Britain at very many points. To make this lesson all the more striking and complete it may be worth while to look more closely at one special case. From the second fraction of the distillation of coal-tar the well-known crystalline substance called phenol, or carbolic acid, may be separated. This substance is often prepared in a pure condition for use in hospitals, and this represents that use of phenol which is perhaps the best-known. Many other important derivatives may be made from it as a starting-point, as mentioned already. A long 'family tree' may be constructed with phenol as the root or basis, and the derivatives as stem and branches. Among the ultimate mentions of the 'family tree' of phenol are to be found popular dyes and many well-known medicines, perfumes, and explosives. Among the dyes are cotton yellow, diamine fast red, nigrosine black, and chrome brown; among the medicines are salicylic acid, salol, and the well-known aspirin; among the perfumes are artificial oil of Wintergreen, and artificial coumarine, or 'new-mown hay'; and among the explosives picric acid and its derivatives. This is a goodly list from one starting-point, and no doubt a similar list could be made from many another coal-tar derivative as a basis.

Coal-tar is produced in every town, but it is not every

town that attempts to work it up into other derivatives. Most towns of moderate size are satisfied to recover the ammonia from the gas-works, and the crude tar is sent to a

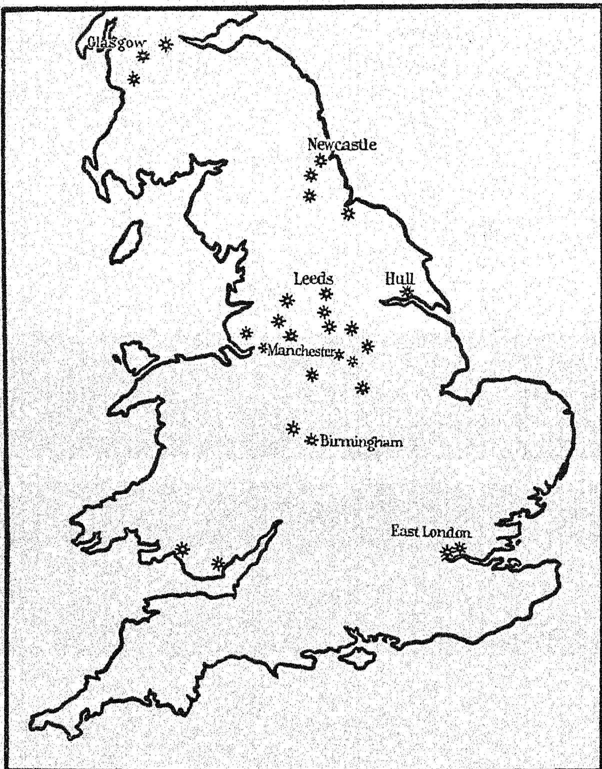


FIG. 19. SKETCH MAP SHOWING THE CHIEF PLACES WHERE COAL-TAR DISTILLATION IS CARRIED ON

tar-distiller. Some of the big cities, however, distil their coal-tar and obtain at least the fractions indicated above. The three great London gas companies and some others in the provinces work up some of the fractions so as to obtain one or more of the proximate products. The Gas Light and Coke Company, who own at Beckton, in East London, the

largest gas-works in the world, produce over 125,000 tons of tar a year, and it pays them to work this up themselves into such products as phenol, pure naphthalene, and many other coal-tar chemicals.

There are tar-distillers and producers of the chief coal-tar products in every considerable chemical region, and more especially those regions of chemical industry which are near the ports. The demand for coal-tar chemicals is, however, so great that many Midland works continue their activities in spite of the tendency for so many works to move nearer to the ports. The chief regions for coal-tar distillation and the making of the more important chemicals are the following: East and South London, North and East Manchester, Birmingham, Oldbury and Wolverhampton, the North Staffordshire Coalfield, the West Riding of Yorkshire, North-east Lancashire, South-east Lancashire, South-west Lancashire, the north-eastern coalfield and industrial region, the South Wales Coalfield, and Bristol, Ruabon, Belfast, Maryport, Glasgow, Edinburgh, and Aberdeen.

In this connexion it may be pointed out too that many makers of coke for blast-furnaces in by-product ovens work up their own tar to some extent; well-known examples are in the coke-producing regions of Durham, South Yorkshire, and Derbyshire.

It would be quite impossible in a work of the scope of the present to follow the manufacture of the coal-tar products into all their ultimate ramifications. A better purpose will be served by selecting a very few of the better-known chemicals or groups of chemicals as given in the official list of the Association of British Chemical Manufacturers and noting, as far as possible, where they are made.

Take, first, salicylic acid and its derivative aspirin; these are made at London, Ilford, Southall (Birmingham), Nottingham, Ruabon, Liverpool, Warrington, and Huddersfield.

The benzoic-acid compounds, such as sodium benzoate, seem to be made chiefly at several works in London and at Ilford, in Essex.

Photographic chemicals are made chiefly in Greater London, at a number of works, and at Nottingham.

Coal-tar disinfectants of various types are made in London, Bristol, Birmingham, Wolverhampton, Nottingham, Hull, Leeds, Dewsbury, Middlesbrough, Manchester and district, Accrington and district, Farnworth (Bolton), Liverpool, Widnes, Ruabon, Maryport, and Belfast.

The chief localities for the manufacture of coal-tar colours are Manchester and district, Huddersfield and district, Leeds, Bradford, Dewsbury, Brighouse, Bury and district (Lancashire), Liverpool, Birkenhead, London and district, Grays (Essex), Carlisle, and Grangemouth (Scotland). By far the greatest quantities of these coal-tar dyes are produced in the Manchester region and in the West Riding region, from Leeds to Huddersfield. It is here, of course, where there is the greatest demand for the dyes.

Closely interrelated with the vast industry in coal-tar chemicals are branches of chemistry connected with other materials, such, for example, as the alcohols, acetic acid, formaldehyde, acetone, ether, citric acid, tartaric acid, and lactic acid, the essences and perfumes, and many other rarer chemicals. These are made in London, Norwich, Nottingham, and in the great chemical regions of the Mersey and the Irwell, the West Riding, and the newer chemical region of South Durham and the Tees.

CHAPTER XVI

ASSOCIATED CHEMICAL INDUSTRIES AND DERIVED INDUSTRIES: SOAPS, GLASS, PAPER, LEATHER, PAINTS, VARNISHES, EARTHENWARE, ETC., RUBBER, ASBESTOS

IT is abundantly clear nowadays that all industries depend to a greater or less extent upon chemicals; those treated in this chapter especially so. They are only once removed from the great chemical industries, and their prosperity is a function of the ready and cheap supply of chemicals as raw materials. The chief aim of this rather long chapter is to point out their location and the way they fit into the general industrial life of the country.

Soap. It has been said that Britain washes the world, and this is true in a measure, for British soaps find their way into every land. Most of the industrial nations make their own common soaps, but Britain still exports special soaps of several kinds, and her commoner soaps have also a great hold in the markets of India, China, and Africa.

The first raw materials necessary for soap manufacture are fats, animal and vegetable oils, and the alkalis, caustic soda and caustic potash. Beef tallow, mutton tallow, coconut oil, palm oil, palm-kernel oil, ground-nut oil, soya-bean oil, cottonseed oil, cocoa-butter, shea-butter, and olive oil are the most important animal and vegetable fats and oils; it will be noticed that, with the exception of beef tallow and mutton tallow, they are obtained from plants which cannot be grown in Britain. The oils are pressed from the seeds or nuts in Britain very largely, the chief places for the industry being Hull and Liverpool.

For the making of the everyday hard soaps the fats are boiled with caustic soda. The soda decomposes the fats, sets free glycerine, and combines with the fatty acid to form a soap. When the saponification of the melt is complete

common salt is added, and this causes the soap to separate out as a curd. The soap-curd is afterward removed to the coolers, and the liquors are taken to the glycerine recovery plant. There are thus three raw materials, fat or oil, caustic soda, and common salt, and two products of the interaction, soap and glycerine.

In many common household and laundry soaps rosin is added to the soap-pan in definite proportions; a rosin soap is also formed, and this blends with the fatty-acid soap. Such rosin soaps are harder and cheaper than soaps made from fats or vegetable oils only. The common alkaline compound silicate of soda is blended with many common soaps. This compounded soap may be sold more cheaply than pure soaps, and may be so made that it has extra cleansing and water-softening properties.

If olive oil, linseed oil, cottonseed oil, or rape-seed oil be saponized with caustic potash, a soft soap is produced; such a soap usually contains the glycerine which is left in the lye when hard soap separates as a curd on the top of the melt. Old-fashioned Scottish soft soap was similarly made from cod oil or whale oil and potash.

Colouring matters, perfumes, disinfectants, and skin tonics are added to some soaps at a convenient stage of the manufacture, and thus the so-called toilet soaps are produced. Soap-powders, or so-called dry soaps, are usually intended as scouring agents and for use with hard water. They consist of powdered hard soaps mixed with soda ash, and frequently with a proportion of powdered borax.

The localization of soap manufacture is now readily explained. Almost every great port has one or more soap-making works, but the greatest number are located in the Mersey-Irwell region, with an extension into North-east Lancashire, in the region from Hull to Leeds and Huddersfield, and in Greater London. The first of these regions is the greatest soap-making district in the world, and contains the largest single works, that of Lever Brothers, Ltd., at Port Sunlight. There are many soap factories in Liverpool itself, and famous factories have long been established at Widnes, Warrington, and in the Manchester district. Special

textile soaps are made in Greater Manchester and in the middle and upper valley of the Irwell, while there are well-known factories which make household soaps in the Accrington district of the Ribble drainage.

In this South and East Lancashire region there is ready access to a tremendous market. The two necessary alkalis are at hand; salt and silicate of soda are available; and there are all the incidental substances, such as phenol, cresylic acids, naphthalene, dyes, scents, and other things which find a place in the great variety of modern soaps. There is the great group of Mersey ports at hand, where at Liverpool, Birkenhead, Runcorn, and up the Ship Canal to Manchester come tallows from Australia, New Zealand, and the Argentine, and the oil seeds and nuts from West Africa, Brazil, and from the cotton-fields of the United States, Egypt, and India. The same facilities which serve so well for import serve also for the export of the manufactured soap and the crude or purified glycerine to the remotest corners of the world.

Glass. This important and indispensable substance is made by fusing pure sand with sodium carbonate and limestone (calcium carbonate); other substances often used are salt cake, or sodium sulphate, and sodium silicate. If potassium carbonate is used in place of sodium carbonate a harder glass of higher melting-point is obtained. Other varieties of glass contain boric oxide, zinc oxide, or lead oxide. If coloured glass be required small amounts of various metallic oxides are added to the usual materials. For example, to obtain blue glass a portion of cobalt oxide is added, for green glass a chromium compound or an oxide of copper, for a yellow glass a uranium salt in very small quantities, for a deep red a cuprous oxide, etc.

The relation to the chemical industries is at once apparent, and one of the factors of localization is explained. The greatest glass-making region in Britain is north of the Mersey, and may be regarded as a part of the great chemical region so often quoted already. Sand and flint are imported by the Mersey, the Ship Canal, the Bridgewater Canal, and the Sankey Canal; the alkalis are, of course, close at hand, and

the various colouring compounds are readily obtained. The glass crucible furnaces consume large quantities of coal, and

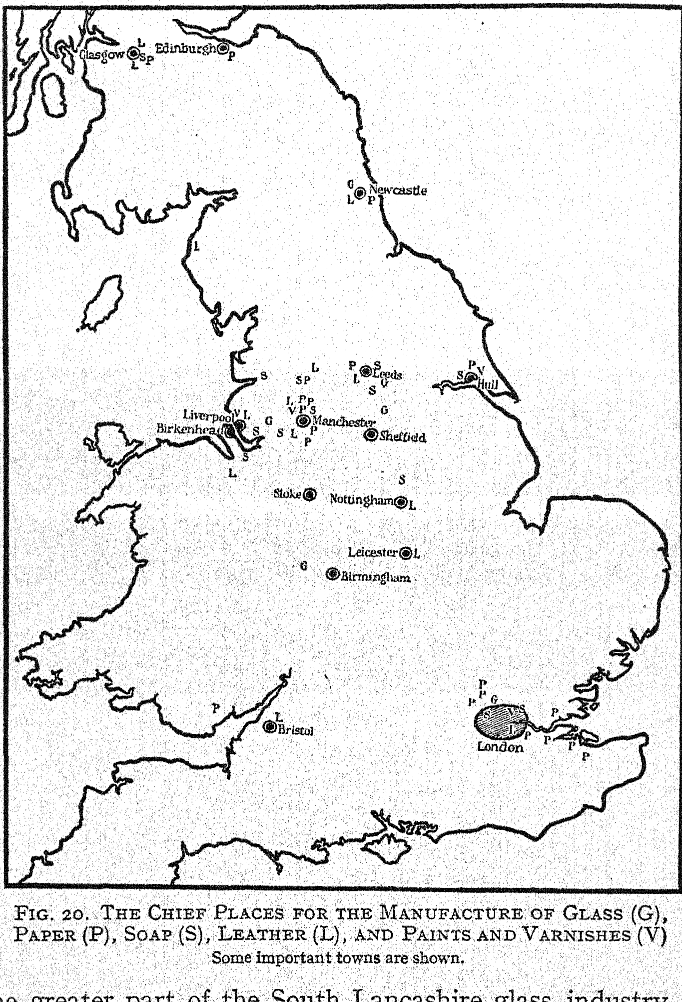


FIG. 20. THE CHIEF PLACES FOR THE MANUFACTURE OF GLASS (G), PAPER (P), SOAP (S), LEATHER (L), AND PAINTS AND VARNISHES (V)

Some important towns are shown.

the greater part of the South Lancashire glass industry is on or quite near the Lancashire Coalfield. St Helens is the foremost glass-making town in Britain, and there are glass-

works also at Newton-le-Willows, at Warrington, and at Manchester.

On the east side of the Pennines is a considerable glass manufacture in the Rotherham-Castleford-Knottingley area, a district particularly associated with the production of glass bottles. Leeds, that city of a hundred trades, shares in this industry.

Another centre is London, where glass-works are found in that region of varied industry, the "East End," and also in the north-western suburbs. Tyneside has many trades, and among these some glass manufacture is included.

A very interesting example of the adaptation of an industry to the other manufactures and general output of a region is the glass manufacture of Birmingham, South Staffordshire, and North Worcestershire. Glass-making has been established there for over a century. Glass-cutting has been highly developed, and the high-grade table glass of the region is well known. Decorative coloured glass, lenses for ships' lamps and railway signals, prismatic glass, and lenses for lighthouses all seem in keeping with the general varied trade of the district. Glass for mirrors is also made there, and the construction of these also falls within the general character of the industry of the district. The production of electric-light bulbs on a large scale also seems quite fitting; and chemical and medical glass is explained by the needs of Birmingham itself and by its position as the industrial capital of a great region.

Paper Manufacture. This is an important and expanding British industry, which illustrates remarkably well the principles laid down in the study of the heavy chemicals (p. 176), and also shows clearly the general tendency of many industries to get away from the raw material and to produce more highly specialized products for the home market and for export.

The raw materials are numerous, but they are well known and readily summarized. Paper is essentially an aggregate of cellulose flakes and fibres mixed with organic and inorganic filling materials, so as to give it 'body' and allow of the coating and enamelling processes. The first raw materials must obviously be composed mainly of cellulose, which is

derived directly or indirectly from plant tissues. For the very best papers cotton rags, cotton waste, short fibres of cotton lint, linen rags, and linen waste furnish the necessary cellulose. Another group of plants includes hard, fibrous grasses and their allies, of which esparto-grass, from Spain, Morocco, Algeria, etc., is the best-known. Similar fibrous grasses are the alfa (halfa) grass of Tunisia and Tripoli, the famous papyrus of the Nile region (from which the name 'paper' comes), and the 'delta' grass of Rumania. Almost every warm temperate, tropical, and sub-tropical region produces some kind of fibrous grass which has been tried or is actually being used for paper manufacture. Excellent paper from bamboos is being made in India. The straw of oats, rye, wheat, maize, and rice are all used, but more in Germany than in Britain; in this country esparto-grass seems to be preferred. An American newspaper came out in December 1928 printed entirely on paper made from the stalks of maize. There are almost unlimited quantities of this 'raw material' available at very cheap rates.

The greatest source of cellulose for paper-making is now wood-pulp derived from coniferous trees—Scots fir, spruce, and hemlock, for example. The wood-pulp comes to Britain from Canada, Newfoundland, Norway, Sweden, Finland, Poland, and Germany. It comes in two forms: mechanical pulp, the wood of which has been ground, washed, dried, and compressed; and chemical, or sulphite, pulp, which has been bleached either by sodium sulphite or by sulphite of lime.

The paper-maker must so arrange his process that as nearly as possible all non-cellulose plant tissue should be got rid of. To do this the esparto fibres, or the wood-pulp, or other plant tissues, are digested with a strong alkali, or with an acid solution of bleaching-powder, or with a strong sulphurous acid solution. When the wood-pulp, or fibres, or rags, have been thus 'digested' the real process of paper-making begins. A machine called a beater is made to beat or bruise the fibres, to make them into a pulp of such a consistency that it will carry water and be stiff enough for the wire cloth and the various rollers over and through which it must now pass in its stage of being converted into paper.

The raw materials mentioned so far are typified by rags, esparto-grass, and wood-pulp on the one hand, a caustic alkali (usually caustic soda), a sulphite, or a chlorine carrier on the other. Here is seen the dependence of the paper manufacture on the heavy-chemicals industry. Into the pulp are introduced selections of loading or filling substances, such as starches, glues, resins, China clay, gypsum, barytes, etc., along with colouring matters; these are introduced in the beating process, or in a special additional process called tub-sizing, nearer the end. These substances which are for filling and 'coating' the paper clearly make another demand on the more varied chemical industries.

Special machinery of a complex and expensive character is necessary at the various stages; such machinery is largely made in the great engineering province of Manchester and district, with Bury as the best-known centre.

The paper manufacture has to adjust itself to several factors as far as may be; these are liberal supplies of reasonably pure water, supplies of the necessary fuel and power, supplies of esparto-grass, wood-pulp, etc., and supplies of the necessary chemicals. It is also an advantage to be near a large market, to which the finished goods can be delivered at no great expense.

As there is an export of over £7,000,000's worth of paper and cardboard in an ordinary year, paper-making mills have an advantage if they are near the ports. There is, however, a far bigger import than export, but this concerns the users of paper rather than the paper manufacturers.

As in some other industries, the little mills, sometimes in remote upland valleys, tend to die out and the industry to shift to the great industrial centres or to the great ports. Certain old-established mills, which produce some speciality in paper, and which have advantages in a good water-supply and cheap power and cheap local labour, still maintain their ground, as in Wharfedale, for example.

The greatest modern British region for the manufacture of paper is that of London and the Thames and its feeders. The North of Kent, from Sittingbourne westward, contains some big modern paper-mills; at Sittingbourne are said to be the

largest mills in the British Isles. There are important mills at Maidstone, Gravesend, Dartford, Northfleet, Greenhithe, and Darenth; and at Purfleet, on the north side of the Thames, almost opposite Gravesend, are the biggest paper-board mills in Europe.

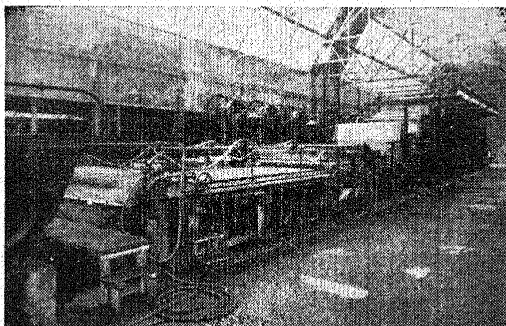
On the south-western and the western side of Greater London are other paper-mills which help to satisfy the voracious appetite of the capital, while to the north-west, in the valleys of the Colne and the Gade, are the works which were established by John Dickinson in 1804, and where in 1806 the founder invented the cylinder paper-making machine for producing a continuous web of paper. This old firm illustrates very well one of the modern tendencies of British manufacture, for while it still makes many kinds of paper in immense quantities, it has also become famous as the biggest envelope-maker in the country. To the word 'envelope' the firm has given a new significance, for the output includes not only the envelope as understood by a layman, but paper containers of every conceivable kind and for an almost endless variety of purposes. A considerable proportion of the firm's immense production of these containers is for the export trade.

JOHN DICKINSON

By courtesy of Messrs John Dickinson and Co., Ltd.

Another famous region for paper manufacture is Lancashire, chiefly round the great mass of the Rossendale Fells, from Burnley, round by Church, Rishton, Darwen, and the Chorley district, to the region where the Tame, the Etherow, and the Goyt come from the Pennine moors to help to swell the volume of the busy Mersey. Here is an almost unlimited supply of reasonably pure soft water from the Millstone Grit

and the Coal Measures sandstones; there is also the great alkali-making region close at hand; the Lancashire Coalfield supplies power and heat for the processes; and there is the busy import and export region of the Mersey and the Ship Canal. The paper manufacture has grown up side by side with the cotton industry because cotton waste and cotton rags formed one of its chief raw materials. The Lancashire makers of fine-calendered papers even yet depend a



PAPER-MAKING MACHINE
By courtesy of Messrs John Dickinson and Co., Ltd.

great deal on cotton and linen waste. The great market of 10,000,000 to 12,000,000 people is another factor, and the cotton and clothing and other industries require immense quantities of packing and wrapping paper in various forms. It may be recalled that Bury is the centre of the paper-machinery industry, and is itself also a great centre for paper manufacture.

A third important region is the eastern part of the Scottish Lowlands, toward the hills, from which again plenty of pure water may be obtained. The great printing industry of Edinburgh draws largely on the paper made here. Still another region which must not be overlooked includes the West Riding slopes of the Pennines, where old-established mills occur far away up some of the remoter valleys, and still carry on the manufacture of some speciality.

The ports have been mentioned. Glasgow, Liverpool, and

Cardiff, on the western side of Great Britain, have their paper industries. Cardiff has quite recently made extensions in its use of esparto for special kinds of paper. On the other side is Hull, with paper-works which include the production of special types of wallpaper.

And to all these there must be added many a paper-mill, more or less isolated, in some other part of the British Isles, where the presence of plenty of good water, perhaps coupled with a reputation for some special brand of paper, keeps an old-established concern going.

Chapter XXVIII, on printing, bookbinding, and publishing, may be consulted at this point.

Leather. This is another important British industry of the second rank which is immediately dependent upon the chemical industry. Its raw materials are of three groups: (*a*) hides and skins, (*b*) preparatory and tanning materials, (*c*) substances (mainly definite chemicals) used in finishing.

The hides and skins comprise a considerable home supply, supplemented by a big import from British India, Australia, New Zealand, British South Africa, Egypt, Sudan, Nigeria, Canada, the Argentine, and Uruguay. The import of these would alone bring about a tendency to set up tanneries at or near the ports.

There is also a considerable import of tanned sheepskins and goatskins, which are taken in hand by the British dresser of sheepskins, who sometimes tans them still further, and, in any case, dyes or stains, marks, grains, and finishes them. So also some tanned hides are imported, but not in very large numbers, and these are finished by the British currier according to the demands of the trade.

Before hides and skins are ready for the tanning processes there is a good deal of preparatory work to be done, and for this there is a call on the chemical industry. Among the materials that are needed are sulphuric acid, hydrochloric acid, lime, sodium sulphide, ammonia, bran, and other vegetable or animal substances from which a putrefactive bath can be made.

The old-time tanning by means of oak bark is almost a thing of the past. Oak extract, chestnut extract, quebracho

extract, hemlock-spruce extract, cutch or gambier, wattle bark and extract, and sumac are the chief vegetable tanning materials. British needs are practically met solely by imports, and here again the ports are of supreme importance to the industry.

Since the eighties of last century vegetable tanning materials have been increasingly replaced by chemical tannings, chiefly chromium compounds and alum. The chromium salts used are mainly potassium bichromate and chrome alum; these are used in company with mineral acids (sulphuric and hydrochloric) and such reducing agents as sodium bisulphite and sodium hyposulphite. Chrome tanning is now commoner than vegetable tanning for the uppers of boots, for example. Satisfactory chrome tanning is now applied to sole leather and belting leather, but vegetable tanning still retains a considerable hold in this heavy-leather section.

It will be seen that here again, in the tanning process, the leather manufacturer must look to the chemical manufacturer and to the ports.

In recent years attempts have been made to produce synthetic tanning materials, in the hope of rendering British tanners less dependent upon sources abroad. These attempts have met with some success, but the new synthetic tannings have not replaced the familiar tanning materials to any great extent. The substances used in one of the more promising of these experiments are cresylic acid, formaldehyde, sulphuric acid, and caustic potash; if this new process should eventually become established it will mean one more link between the leather industry and the chemical industry.

When the hides or skins are tanned—that is, converted into leather—there come next the various finishing processes. Now there come into play many special machines and a number of chemicals, together with natural colouring matters, such as fustic and logwood. Some of the chemicals are copperas (iron sulphate), potassium bichromate, specially made 'inks,' oxalic acid, albumen, starch, farina, and many kinds of coal-tar dyes. The finishing processes thus make further demands on the chemical industry.

The leather industry has tended to becóme more localized and specialized within the last generation of tanners. The little tannery which formerly existed in almost every town is almost a thing of the past, though one here and there has been modernized and made to produce leather to serve the needs of some local industry. One or more tanneries may be found in almost every considerable port and in or near every region of dense population. Bermondsey, in South-east London, is the leading district, followed by Leeds and district. These places carry on both chief branches of the industry, heavy leather (hides of cattle and horses) and light leather (skins of sheep and goats). The Mersey region is again important. Greater Liverpool has about twenty tanneries, some engaged in the heavy-leather trade, others in the light-leather branch. Warrington and its suburb Penketh have a considerable heavy-leather industry. There are well-known heavy-leather factories at Walsall, Bolton, Bury, and Whitehaven, and large light-leather works at Colne (Lancashire), Nottingham, and Wrexham.

Paints, Varnishes, and Enamels. The manufacture of these commodities is another distinct 'side-line' to the main chemical industry of Britain. It is an important industry in itself, and it is also doubly important in the way it is linked up with the soap, paper, and linoleum manufactures on the one hand, and with farming on the other.

The primary raw materials are, first of all, the pigments used. These are generally oxides or salts of metals, of which a few are of natural occurrence, but the great majority are made, or purified and rendered adaptable, in the chemical works.

Without going deeply into the subject, or attempting a technical description, a few examples can be given which illustrate principles and fit in with the general scheme of this book. White pigments are the most important of all, because of their own extensive use in white paints, and because they are mixed with other coloured pigments to form various coloured paints. White lead is the common, historic white pigment, and is made from sheet lead by a number of chemical processes. Because of the poisonous nature of white

lead and other lead salts their use is forbidden by many public bodies, and compounds of barium, zinc, and titanium are now substituted. From the point of view of the painter, the objection to these has been their lack of opacity. Titanium dioxide is said to be a promising compound for adding to white paints to increase their opacity. A well-known white pigment, widely used as a basis of white paints, is lithopone, which is a mixture of white zinc sulphide and white barium sulphate.

One of the most interesting pigments is artificial ultramarine, which is used as the basis of some blue paints, and then by mixture with various yellows and reds pigments which are green or purple are obtained. Artificial ultramarine is made by an empirical process, which was discovered accidentally and then worked out by experience. It is now made by fusing a mixture of kaolin, sulphate of soda, soda, charcoal, and sulphur, the details of the process being jealously guarded by the makers. Only two makers are listed in the *Official Directory of Members of the Association of British Chemical Manufacturers*, located at London and Hull respectively.

The above examples out of a possible long list will give the reader an idea of the part played by the fundamental chemical industries in the paint industry. The pigments are ground up with linseed oil or its substitutes; other substances used are either turpentine or white spirit and one or more of the resins or gums. Some of the oils in use are linseed oil, hemp-seed oil, china-wood oil, and soya-bean oil; the principal gums are lac, from India, kauri gum, from New Zealand, common pine resins, and pitch or bitumen. Among solvents, used for making varnishes and lacquers, are methylated spirit, benzene, amyl alcohol, and turpentine.

The above is somewhat of the nature of a mere enumeration, the object being to emphasize the relation to the chemical industry and to lead up to a further mention of the dependence upon the ports. Probably Hull and district is the first region in Britain for the making of paints and varnishes, because Hull is the largest centre for the production of vegetable oils in the country. Among the imports of

oil seeds into Hull are cottonseed, linseed, palm kernels, soya-beans, rape-seeds, castor-seed, groundnuts, sunflower-seed, and sesame-seed. Liverpool and the Mersey probably come next to the Humber in the import of oil seeds, turpentine, and resins. It is significant that it was at Bootle, in 1885, that Samuel Banner introduced white spirit as a substitute for turpentine. White spirit is one of the fractions obtained in the distillation of crude petroleum. There are great oil-cake factories at Liverpool, as every one is reminded who approaches that city by railway into Exchange Station.

The seed-crushing mills of the Humber and the Mersey not only supply oils to the soap-maker and the manufacturer of paints and varnishes, but the oil-cake is eagerly bought by the dairy-farmer and the cattle-rearer. The oils, gums, and resins are also supplied to the maker of linoleum, oil-cloth, and such embossed 'papers' as 'Lincrusta' and others. In the same regions, and from the same groups of factories, purified oils are supplied to the margarine-makers. So that here is a fine cycle of operations and products which have chemical industries and imports of oils, fats, resins, waxes, and gums as their basis; a good example of the interdependence among modern industries.

The Earthenware, Pottery, and Chinaware Industries

This branch of industry or group of industries may be regarded as overlapping the mining and quarrying group on the one hand and the chemical group on the other. The basis of the industries is clay, of which there are many kinds. The clays and shales were dealt with in Chapter IX; the location of the finer wares has been left to this section.

There is one British locality where the finer kinds of earthenware are made on a big scale; this is the middle of the North Staffordshire Coalfield. There a string of towns stretches from south-south-east to north-north-west, forming almost one continuous town. From south to north the pottery centres are Longton, Fenton, Stoke-upon-Trent, Hanley, Burslem, and Tunstall. Here are a vast number of pottery-

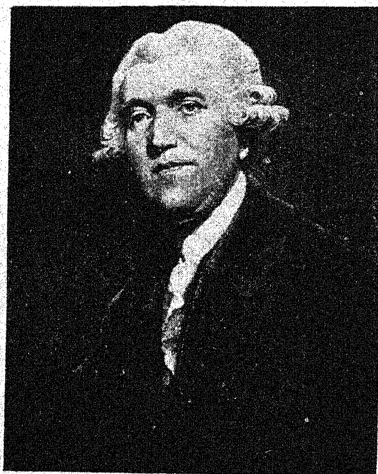
works of various kinds, along with many allied industries, and about 35 per cent. of the workers of the region find employment in the industry.

One of the important early factors which helped the development of this industry was the presence of appropriate Coal Measures clays and marls. These are suitable for the manufacture of drain-pipes, tiles, sanitary ware, and other forms of either glazed or unglazed common earthenware, but not for fine chinaware or porcelain. The manufacture of coarse earthenware is still carried on, but the fame of the district is founded on the finer products, and for these most of the raw materials are imported or manufactured in the district from imported materials. The fireclays and marls are suitable for the making of the seggars, or 'ovens' in which the pottery is baked, and there is, of course, the coal for heating the furnaces. China clay is imported from Cornwall and Devon, *via* the Mersey and the Grand Trunk Canal, which goes through the district, or by road transport from the Mersey. Clay is also brought from Dorset for certain kinds of work; flint is brought mainly from the ports of the Normandy coast and also from Norfolk; felspar is imported from North Wales and from the granite regions of Norway and Quebec; and bones, from which bone ash is made, are brought from Montevideo, Buenos Aires, and Rosario. The glazing chemicals, including salt, and the paints and colours for staining are brought from the chemical region of the Mersey and partly manufactured in the district.

There was a pottery industry in that region at the dawn of the great industrial change in 1720–30. The wonderful progress afterward was largely due to one master-mind, the famous Josiah Wedgwood. Born in 1730, he learned the trade of pottery-making as it was then known; it was the trade of his father and his grandfather too. He lost the full use of his right leg when a youth of fifteen through disease in the bone, following a virulent attack of smallpox, and this prevented him from continuing as a 'thrower' in the potworks.[1] He had time to read and think, and he began a course of self-education, paying particular attention to chemistry.

[1] His leg was amputated twenty-two years later.

He began business on his own account in 1759, and made such progress that he became easily the most famous potter of his time, and the name "Wedgwood ware" grew to be known all the world over. He was active in supporting the making of new roads through the district, and later he entered with great spirit into the scheme for the Grand Trunk Canal. He cut the first sod of the canal on July 26, 1766, and when the new waterway was partly completed he built on its banks the famous Etruria Works. This was one of the earliest of the English canals.



JOSIAH WEDGWOOD

There were other famous and successful potters in the region, and the industry became so firmly established that all the changes of one and a half centuries have not disturbed its supremacy. The 'Potteries' of North Staffordshire is still the most famous region in the world for its own kind of work in earthenware.

There are other works for fine chinaware and porcelain at Worcester, Derby, Burton-on-Trent, Clifton Junction (near Manchester), Manchester, Langley (Nottinghamshire), Birmingham, Weston-super-Mare, Glastonbury, Clevedon, Exeter, Bovey Tracey, and Barnstaple.

The earthenware and china industries find employment for over 50,000 people.

RUBBER AND ASBESTOS

There are many 'side-lines' to the great group of 'derived chemical industries,' but it is not possible to discuss more than two of these in the present volume.

Rubber. The history of the rubber industry all falls within the last four hundred years, and as it affects British industry in general is practically all included within one and a quarter centuries. The use of rubber has now penetrated so far into other industries that there is some reason for calling the present epoch the Rubber Age.

It is not necessary to enumerate the various forms and uses of rubber in the home, the office, the hospital, the school or college, every form of industry, and almost every kind of sport, nor would it be possible to do so except by giving a very lengthy catalogue. Some of its less apparent forms, as in 'rubber paper,' or as thin films deposited from solution, in the mackintosh process, or in such substances as vulcanite or ebonite, illustrate the great adaptability of this wonderful substance.

Raw rubber was first well known to British scientists and technologists from the valley of the Amazon, and even to-day some of the best rubber in the world is the Para rubber, collected and prepared from the 'wild rubber' trees of that equatorial forest region. Largely through British enterprise, the Brazilian rubber-tree has been acclimatized in other hot lands, and now, instead of collecting it from scattered trees in an equatorial jungle, there are plantations of trees, set out row upon row, cultivated with scientific care and knowledge, and giving a high yield of plantation rubber. To-day more than 98 per cent. of the world's rubber-supply is derived from plantations. The output of the original famous region of the Amazon forests remains little altered, and stands at about 25,000 tons per annum, while the plantations yield over 670,000 tons per annum. The chief world-regions for plantation rubber are the Malay Peninsula, Burma, India, Ceylon, Sumatra, Java, French Indo-China, and Borneo, and one of the greatest collecting marts, from which large quantities are shipped to Britain, is Singapore. Equatorial British Africa and the British West Indies also contribute a share of the rubber required by British industry.

In the preparation of raw rubber for industry the chief processes are milling, or mastication, compounding, or mixing with other substances, and vulcanization, or heating with

sulphur or sulphur compounds and other chemicals. To carry out these preparatory operations demands complex and highly specialized machinery and many types of chemicals; and it is easy to understand why such a large share of the British rubber industry is found near the ports and within reach of the engineering and chemical industries.

London has many merchants and dealers and a special rubber market. Many of the great provincial manufacturers have London offices and showrooms. Greater London has also its manufactures of various kinds of rubber appliances, mostly located in the east, at Poplar, Silvertown, Canning Town, Hackney Wick, and Stepney, in the south-east, at Bermondsey, and in more or less distant suburbs, as, for instance, at Mitcham.

Rubber manufactures are scattered all over the provinces, and there is scarcely a big town which is not represented in lists such as those of *Stubbs*. There are certain towns and their surrounding districts which are more important. Manchester, with the surrounding towns, is by far the greatest rubber-manufacturing district in Britain. The eastern and north-eastern parts, such as Ancoats, Miles Platting, and Clayton, stand out as regards the variety and total volume of work done. The rubber work of this particular part of Greater Manchester is obviously related to the variety of chemicals readily obtainable in that district. Other parts of that region are Salford, Pendleton, Trafford Park, Eccles, Hyde, and Failsworth. The manufacture of rubber is also carried on in a number of other Lancashire towns, of which the chief are Rochdale, Bolton, Blackburn, Preston, and Leyland. There is one of the largest rubber-works in Britain in the last-named town.

Liverpool, of course, stands somewhat apart from the great industrial towns of East Lancashire, but it has a big share of the rubber industry, as might be expected of a large port which is also near a great chemical region. Other towns which are in the front rank of rubber-manufacturing districts are Birmingham, Edinburgh, and Glasgow.

Other rubber-like substances which are used in British industry are gutta-percha, gutta-jelutong, and balata. In a

sense, these may be regarded as inferior kinds of rubber or rubber substitutes. The last-named, which is widely used for certain kinds of belting for machinery and for the soles of boots and shoes, is obtained mainly from British Guiana and the neighbouring parts of Venezuela and Brazil. It is imported chiefly to Liverpool and London.

Asbestos. This is rapidly becoming one of the world's most important non-metallic minerals, its striking and useful properties being its resistance to fire and to any form of chemical change, as well as its fibrous character and comparative softness. It can be 'woven' into fabrics, and it can readily be blended with many other resistant chemical substances to make various forms of fire-resisting and non-conducting materials.

Britain has practically no true asbestos in the home country; her supplies are derived almost entirely from Quebec Province and from the Rhodesias.

Again the ports and the chemical regions seem to attract the new industry. Glasgow is, perhaps, the most important single port, closely followed by Liverpool. The chief area in Britain for the asbestos industry is East Lancashire and neighbouring parts of Cheshire and Yorkshire. Manchester is again the focus of this region of the industry, with Rochdale, Preston, Wigan, Stalybridge, Huddersfield, and Halifax sharing in the manufacture. Rochdale is by way of becoming a most important town for asbestos goods of various kinds, including asbestos millboard. Other important towns in the industry are Newcastle-on-Tyne, Hull, Bradford, Birmingham, and Cardiff.

SECTION C

THE TEXTILE INDUSTRIES

CHAPTER XVII

THE TEXTILE INDUSTRIES: GENERAL

THIS is an exceedingly important group of British industries. The included industries are not as basic or fundamental as those of coal, iron, and ships, discussed in Section A, but they find employment for more people than any other group of manufacturing industries, they produce a bigger share of national wealth, as measured by exports, and they are probably the industries by which Britain is best known abroad and by which her reputation is judged.

The simile of Britain as a shopkeeper may be used again. Britain makes a great variety of goods for sale abroad and for use at home, and the former vastly outweigh the latter. In her foreign shop-window are her goods for export, for sale abroad, and the textile industries fill more than one-quarter of that window. To put this into figures, the total domestic exports from Great Britain and Northern Ireland in 1937 were valued at £521,594,000 sterling; the textile exports of all kinds accounted for £138,235,000, or about 26 per cent. of the whole. This vast amount of £138,235,000 sterling represented very great purchasing power abroad for foods, raw materials, and luxuries. Of course, the textile industries also produced a vast amount of goods for home use. This great group of industries found direct employment for over a million people in 1935.

The textile industries deal, in general, with woven fabrics of many kinds; the word 'textile' comes from the Latin verb *tego*, *tectum* ("to weave"), and more directly from the Latin adjective *textilis*. These industries, therefore, deal with fabrics woven in some kind of loom. The broad principle

underlying the whole group is that two sets of fibres are intimately crossed, in an 'over and under' manner alternately. One set of fibres is arranged longitudinally; this is the warp; the other fibres in the cloth, called the weft, are made to cross transversely. In the simplest case one weft thread is carried across the whole of the warp threads, going *over* and *under* each warp thread alternately; then, when the weft thread has crossed the whole of the warp threads, its continuation is sent back across them again, and goes *under* and *over* each warp thread, again alternately. A tool called a shuttle carries the continuous weft thread, and the mechanism of the loom lifts and lowers the alternate warp threads at each passage of the shuttle. Suppose the shuttle is passing from right to left; the warp threads 1, 3, 5, 7, etc., are raised and the threads 2, 4, 6, 8, etc., are lowered by the mechanism of the loom. The shuttle, therefore, goes under the threads 1, 3, 5, 7, etc., and over the threads 2, 4, 6, 8, etc., carrying the weft thread with it, of course. At the next 'pick,' or beat of the loom, the shuttle passes from left to right; now the threads 2, 4, 6, 8, etc., are raised and the weft thread is carried under them, while the threads 1, 3, 5, 7, etc., are lowered, the weft thread being carried over them.

At the end of each pick or beat of the loom a new weft thread has been inserted through the warp threads. Between the picks the last crossing of the weft thread is pushed close up to the previous one, or as close as is necessary, according to the desired texture of the particular cloth being woven. This whole procedure makes a cloth or fabric of the necessary closeness or firmness of texture, and of this there is an infinite variety, from open threadwork web to some of the exceptionally fine cotton serges or gaberdines.

The reader will see that there are three essential movements, or motions, as they are called technically: (i) the lifting and depressing of alternate threads, so as to give a passage for the shuttle (this is called 'making a shed,' or simply 'shedding'); (ii) the passage of the shuttle carrying the weft thread (this is 'making a pick,' or 'picking'); (iii) pushing up the last weft thread into the desired closeness to the previous thread (called 'beating up'). These

three essential motions, shedding, picking, and beating up, are all carried out automatically by the loom; the weaver has to see that the motions are duly carried out, to replace the shuttle when its spool or bobbin or cop of weft is finished,

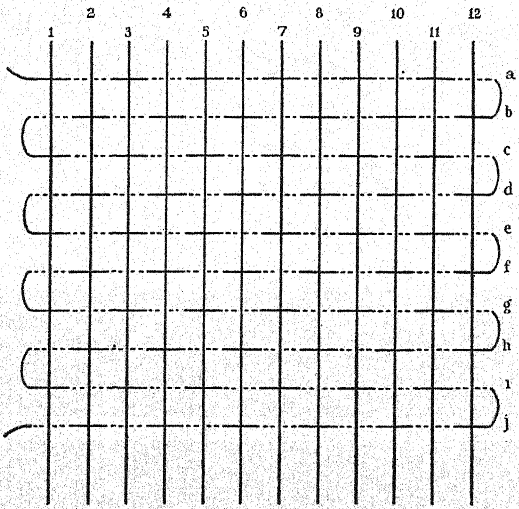


FIG. 21. DIAGRAM TO ILLUSTRATE THE PRINCIPLE OF PLAIN WEAVING

The vertical lines represent warp threads, or 'ends,' as they are called in the industry; the horizontal lines represent a continuous weft thread carried through the warp threads by a shuttle. First, the mechanism of the loom lifts the threads 2, 4, 6, etc., and depresses the threads 1, 3, 5, etc.; this is 'shedding.' Second, the shuttle carries the weft under the lifted threads 2, 4, 6, etc., and over the depressed threads 1, 3, 5, etc.; this is 'picking.' For the next 'pick' warp threads 1, 3, 5, etc., are lifted and threads 2, 4, 6, etc., are depressed, and the shuttle, on its return journey, carries the weft thread through the warp threads again. Between each 'pick' a mechanism beats up the 'picks' of weft *a, b, c, d,* etc., as close as desirable; this is 'beating up.' The separate warp threads ('ends') are fixed as close as may be desired. There is no 'beating up' of these threads.

to adjust and tie any warp threads which are broken in the process, and to watch the cloth generally during the whole process, in order to see that the loom is doing its work properly.

The foregoing gives the general principle of simple weaving, but each motion is capable of much variety. The shedding

is rarely the simple lifting of alternate threads; frequently more than one shuttle is used; and there is much variety in the manner and intensity of beating up. Add to these variations those possible in the arrangement of the warp threads according to colour, thickness, stretch, and nature of fibre, and those possible by varying the weft, and it at once becomes apparent that the variety attainable can only be fully appreciated by those who are experts in the industry.

Every warp, of whatever fibre it may consist, has its own individual characteristics, and every loom seems to have its own idiosyncrasies too; weaving is not necessarily, therefore, merely a dull, mechanical operation. It is true that it can be very tiresome and exacting, but it is seldom lacking in variety. The unexpected frequently happens in a textile factory. Weavers are not mere machines, and do not act as such; they more generally show considerable independence of outlook and character, and not infrequently they bring to bear great skill and ability in the adjustment of loom and fabric to each other. They deal with a work in which there is immense variety in the arrangements and infinite variety in the results. Wages in the textile industries are therefore generally relatively high, and weavers and others engaged in these industries are usually noted for initiative, ability, and thrift.

The great central operation in the textile industry is the action of the loom, the bringing together of warp and weft; this is fundamental, and has been so from time immemorial. There are many other considerations, however, to be appreciated. The fibres themselves are very varied; the chief at the present day are wool (and many fibres allied to it), cotton of many varieties, linen, jute, ramie, sisal, and other similar fibres, and within quite recent times there has come into the industry the first artificial fibre, or group of fibres, to which the general name of artificial silk[1] has been given; these fibres will receive attention in subsequent chapters.

The preparation of the fibres before the weaver can do his work often involves long, complex, and costly operations; these are included in the spinning and preparatory group,

[1] Sometimes the American name, 'rayon,' is used.

the purpose of which is to take the natural fibres, which may be short and irregular, and to join them together in the form of a continuous thread called yarn. The yarn may be weft or warp, which is used as explained already. When the cloth leaves the loom much has still to be done; in a general sort of way these varied operations may be grouped under the term finishing. Throughout the whole of the processes the chemical and engineering industries are continually contributing their quota to the perfection of the desired results. These results will be dealt with to some extent under the various chief branches.

From all this it should be quite obvious that the great group of textile industries is intimately connected with and dependent upon other more basic industries. The spinner of the fibres, the weaver, the finisher of the cloth—these operators are obviously interdependent. There is a still wider dependence, however, upon coal and coal-mining, upon iron, steel, and engineering, upon the chemical industries, and upon transport in all its phases, by road, by rail, by canal, and upon the sea. A dispute in the coal-mining industry may bring the textile industries to a standstill; in the past a railway dispute has done the same, but road transport has made some difference in this respect. The continued progress of the industry is dependent upon the applications of chemical science, and upon new inventions and new modifications of machinery.

CHAPTER XVIII

THE WOOL TEXTILE INDUSTRY: ITS HISTORY IN BRITAIN

THE primary needs of man are food, clothing, and shelter. When early man had learned to make for himself clothing which would keep out the cold and the rain and wear reasonably well he had made a great step forward in civilization. Men who could spin and weave and make their clothing, instead of being dependent upon the skins of animals taken in the chase, were 'civilized.' The wool of sheep was the chief raw material used for the making of clothing in the countries of North-western Europe, supplemented in later times by the fibre of the flax plant and later still by cotton or 'vegetable wool.'

During the thousand years of British history from the first coming of the Romans to the invasion of the Normans there are only occasional references to this and other industries in the British Isles. Some of the later Roman writers make mention of British wool and British cloth. There is evidence that a home industry in wool of some importance existed in Anglo-Saxon England. Charlemagne wrote to Offa, King of Mercia, in 796, asking that the cloaks sent from England should be made of the same pattern as in old time; so that there seems to have been an export trade in woollen cloth even in those early days. Alfred the Great's mother was skilled in the spinning of wool, and Edward the Elder, following the example of Charles the Great, set his daughters to work wool; this was at the beginning of the tenth century.

In those early days the spinning and weaving of wool was a domestic occupation, probably without much attempt at organization; but by the twelfth century some external organization had been introduced. Weaving had become so important that guilds of weavers were formed in most of

the leading towns of England—for example, London, Winchester, Lincoln, and Huntingdon.

In the thirteenth century the leaders in England became concerned about the growing export of wool, to Flanders chiefly, and the import of cloth, and some measures were taken to restrict that export. At the same time an appeal was made to the patriotism of the English people, that they should wear cloth woven in England. More promising still, in this direction, was the great work of Edward III in the fourteenth century. The old-established domestic industry, fostered and helped though it was by the early guilds, had already begun to decay; the English had apparently not kept abreast with progress, and their woollen cloth was inferior to that made in Flanders. Thomas Fuller, in his quaint, forcible way, says that the English weavers were ignorant of their art compared with the weavers of the Low Countries —"their best cloths no better than friezes, such their coarseness for want of skill in the making."

Up to this time the Flemings and the Netherlanders had depended upon England for much of their raw wool, which they had worked up into excellent cloth for those days. As is often the case in manufactures, those who were farther from the origin of the material got the best of it—had most of the profit. An old Flemish saying had it "We buy the fox's skin from the English for a groat, and sell the fox's tail back to the English for a guelder." To quote old Thomas Fuller again: "The Duke of Burgundy . . . initiated the Order of the Golden Fleece; wherein, indeed, the fleece was ours, the golden theirs—so vast their emoluments by the trade of clothing."

Edward III therefore adopted the policy of encouraging Flemish weavers to come and settle in England. The year 1331 was a momentous one in the development of British industry. In that year John Kempe, "a weaver of woollen cloths," with his servants, his workmen, and his apprentices, came to Norwich, already a great centre of the industry, and settled there. Kempe afterward went north-west to Kendal, in Westmorland, where in due course he started the manufacture of the famous Kendal green cloth. In the year 1337

this policy of importing skilled workers was carried a stage farther; and a general offer of protection was made by the King to all weavers, fullers, and dyers who would come. Among these Flemish artisans were others in addition to workers in wool; there were linen-weavers, silk-workers, clock-makers, and other mechanics. Britain received a tremendous accession of knowledge and skill in those eventful years, and much of her modern fame as a maker of textiles is due to the acquisition of Flemish skill and experience by the energetic and determined British artisans.

These foreign artisans settled in many of the towns where wool and cloth were already important. They were promised that "of whatsoever country they be, which will come into England, Ireland, Wales, and Scotland, within the King's power, shall come safely and surely, and shall be in the King's protection and safe conduct." Some of the towns where they settled were London, York, Norwich, Bristol, Manchester, Rochdale, Halifax, Colne, Kendal, and Abingdon. In many of these towns there are still current the names of some of those artisan-adventurers of the early fourteenth century. The name of Kempe, mentioned above, stands out among the names of these Flemish weavers; it is significant that there are Kemps prominent in the cotton industry to-day, at Manchester, Rochdale, and other places.

It was too much to expect of human nature that these foreign workers would be everywhere warmly welcomed by British workers. They seem to have been made more welcome in the smaller towns and the country districts, where the power of the guilds was not so great as in the 'guild towns.' It took nearly two centuries for the experiment to justify itself, but by the close of the Barons' War and the general settling down that followed the men from the Low Countries had been largely assimilated and had helped to make the first great contribution to the progress of industrial Britain.

Meanwhile the farmer had been making his contribution too. The breeds of English sheep had been vastly improved, especially in the eastern, south-eastern, and southern counties. Those keen agriculturists and sheep-breeders, the Cistercian monks, had been at work in remote country districts,

and had made their contribution. The result was that by the sixteenth century sheep-rearing had become a profitable type of farming. The demand for wool increased so much that sheep-farming supplanted ploughing to an extent which alarmed many keen observers of those days. Other causes helped; it is seldom that a revolution in industry, or in the face of a country, can be put down to one cause only. In this case the Black Death and the concurrent break-up of the old manorial system helped to make labour scarce and dear, and it was easier for landowners, as well as more profitable, to turn land into sheep-runs than to continue the growing of corn and roots, to the great scandal of many a patriotic observer of those times.

The first of the great Industrial Revolutions had thus taken place in England; from the fourteenth century to the middle of the sixteenth England had passed from being a wool-exporting to becoming a wool-manufacturing country. In the reign of Edward III the export of wool was estimated at about 30,000 sacks a year; in the middle of the sixteenth century there was little export of raw wool, but the export of English cloth had grown to such an extent that famous weaving towns such as Bruges and Ypres were already feeling the effects of English competition. English woollen cloths were by this time finding a market all over the then known world. By strenuously improving her own manufactures England had secured her own home market, and she was now in a position to battle with and to displace her competitors from foreign markets. It was this revolution that laid the foundation of the modern industry in wool textiles in Britain, and through this of the vast textile industries of modern times.

The wool textile industry was firmly established by the sixteenth century, and it remained the most important industry after agriculture until the nineteenth century. It was for five hundred years or thereabouts regarded with peculiar interest, and was often treated with especial favour by royalty and by Parliament. The fact that the Lord Chancellor's seat in the House of Lords is a woolsack is an abiding testimony of the regard in which wool was held. A

declaration of Parliament in 1454 said "the making of cloth within all parts of the realm is the greatest occupation and living of the poor commons of this land." Camden, in his *Britannia* (1607), describes English cloth as "one of the pillars of the State." Bacon, Lord Verulam, spoke of it as "the great wheel of the realm." James II, in a proclamation issued just before the Revolution of 1688, described it as "the staple manufacture in this our kingdom." Defoe, in *A Tour through England and Wales* (1724–26), described it as "the richest and most valuable manufacture in the world." The well-known *Wealth of Nations*, by Adam Smith, appeared in 1776, and in it he says: "Our woollen manufacturers have been more successful than any other class of workmen in persuading the Legislature that the prosperity of the nation depends upon the success and extension of their particular business."

Over and over again, Parliament revealed its solicitude for the wool industry by passing Acts which showed special favours. After the Restoration of 1660 this tendency was very marked. In 1665 an Act was passed that all the dead should be buried in woollen shrouds, an Act which was not repealed until 1815. Arthur Young shrewdly remarked about this Act that it was "forcing the dead to consume what the living were inadequate to purchase."

In 1677 a resolution of the House of Commons required all persons "to wear no garment, stockings, or other sort of apparel, but what is made of sheep's wool." In a similar temper, in 1697, the House of Commons ordered that only gowns made "of woollen manufacture" should be worn by professors and students in the universities and by all judges and magistrates. In 1720 an Act of Parliament was passed which prohibited the use of printed calicoes, "since the wearing and using does manifestly tend to the great detriment of the woollen and silk manufacturers of this kingdom." The reader will note that silk had now come within the favoured zone, but cotton was still outside the pale.

As the wool industry has been the master textile industry, and, indeed, the only important one in Britain, for many centuries, the chief phases of its organization through the

ages may now be described very briefly; for the complex and highly effective organization of British textile industries in modern times cannot be fully understood without reference to those institutions and practices in which are the roots of modern conditions.

Three organized phases may be recognized: (i) the era of the guilds, from the beginning of the twelfth century to the latter part of the sixteenth century. Now, one phase of industrial organization does not pass into another suddenly; the transition is gradual, and usually takes place more rapidly in some places than in others. Remembering this qualification, one may see that the guild era was replaced by (ii) the mercantile era, or the period of the so-called domestic system; and this in turn was replaced by (iii) the factory system of mass production, at the beginning of the nineteenth century.

Under the guild system the industry was largely financed by the artisans themselves; the workers usually owned their spinning-wheels, their looms, their fulling-stocks, and their dye vats. They sold not their labour, but the products of their labour; and as craftsmen they preserved a good deal of independence. It is probably the same spirit of independence which has descended in some measure to the modern textile artisan, who does not object to being called a spinner or a weaver, but who is apt to take offence if he is described as a 'hand.'

In the guild system there was little room for the outside financier to come in and control the work. Usually the spinner bought his wool and sold his yarn; the weaver bought his yarn for weft and warp, and sold his cloth; the dyer or finisher bought the unfinished cloth from the weaver, completed the processes, and then sold to the man who made the clothing. Practices such as these died hard, especially in the more remote districts among the hills. An aunt of the present writer was a hand-loom weaver away up on the sides of the Pendle Range; she wove at her loom and took her woven pieces to the Piece Hall at Colne, some four miles away, and sold them. She often related how she sold one piece particularly well in, probably, the year 1840. She

thought the good sale indicated an extra treat for the family at the week-end, and she brought home from the town a *2d.* rye loaf! The writer has always understood that she obtained warp and weft 'on credit,' wove her piece, sold it, and paid for the warp and weft from the proceeds. This was a sort of relic of the early guild system, but of course there was no guild.

A weavers' guild was a body of weavers who lived in the same town and who combined together for mutual protection; not protection of wages or hours of labour, for there were no wages in the modern sense, and every man was his own master as regards hours of work. The guild consisted of masters, journeymen, and apprentices; the apprentice in time became a journeyman, and from the ranks of journeymen came the masters. The latter were not masters as is popularly understood in industry to-day; they were masters of their craft.

The chief functions of the guild were to look after the sick, the poor, and the needy among their members; to settle any disputes which might arise between them; and, above all, to maintain a high standard of work. The members seem to have believed that an industry was a public service, and that anyone guilty of poor workmanship was bringing discredit upon the guild. It sometimes happened that a master employed one or two journeymen and took responsibility for their work, thus anticipating the next phase. There was, however, no permanent and distinct class of employers and of employees, and the difficult problems of capital and labour which are a disturbing feature of the modern phase did not arise.

The guilds grew in numbers and in power during the thirteenth, fourteenth, and fifteenth centuries. By the end of the fourteenth century there were strong guilds in many towns. The first weavers' guild seems to have been the one founded in London in the year A.D. 1100; similar guilds with like privileges founded in the twelfth century were at Lincoln, Oxford, York, Winchester, and Nottingham. Later there were also strong guilds at Norwich, Beverley, Hull, Coventry, Cirencester, and Exeter. This gives some idea of

the localization of the organized wool industry in medieval times; but there was some work in wool—spinning, weaving, fulling, and dyeing—carried on in many a small town in the country.

The sixteenth century saw the establishment of a new phase, in which capital played a much more important part; this phase lasted until it was in turn displaced by the era of machinery, of the large factory, of specialization, and of production on a large scale. The middle period is sometimes called the domestic system; and some have called the era the commercial period. On the whole, it seems to the writer, the name mercantile system connotes more accurately and completely what actually took place.

During the fourteenth and fifteenth centuries the wool manufacture had continued to grow, and such well-known cloths as Kendal greens, Norwich fustians, Kentish broadcloths, and Devon kerseys had become famous both at home and abroad. At the same time the ideal, early guild system had changed. Those who made the cloth gradually ceased to sell it direct to the user, but to a merchant, who also bought from other weavers; here was the beginning of the 'middleman' in the wool industry. In London these buyers and sellers of cloth were the 'drapers,' who were sufficiently numerous to form a strong company, the "Drapers' Company," in the fourteenth century. This company still exists, and is well known for the liberality of its benefactions and the discretion with which they are allotted.

At this time, too, trade was being opened up abroad, and obviously the individual master-weaver could not very well sell his cloth in France or in the Baltic lands; some kind of middleman or merchant was now a necessity. The work might still be done in the homes of the workers, who were members of the guild, but even master-weavers were now losing their complete independence. A wholesale dealer, a merchant, bought the raw material for warp and weft, supplied it to the workers, paid them for their labours—that is, paid them wages—and the finished cloth was his property; or, put more concretely, the merchant bought wool from the farmer, gave it out to spinners, passed the yarn on to weavers,

and in due course to dyers and fullers. He then took the finished cloth to one of the cloth fairs or markets and sold it. He took most of the risks, and he naturally expected a profit; he was the early capitalist, and the artisans were becoming wage-earners.

It was almost inevitable that with the mercantile system there should grow up some form of factory system. If the merchant was finding work for twenty spinners and for ten weavers, why should he not house them in some common building? All the more so as the tendency was for the merchant to own and supply the looms. Hence, though the guilds were, on the whole, opposed to such tendencies, the inevitable segregation into 'factories' or 'workshops' took place.

Mention of a very few of the men who have been described as the rich clothiers will help the reader to visualize the distribution of the wool industry. The most famous of these merchant-manufacturers was John Winchcombe, afterward known in history, and especially in legend, as Jack of Newbury (Newberrie). He is described in Fuller's *Worthies* as "the most considerable clothier (without fancy and fiction) that England ever beheld." He possessed two hundred looms, on which

> Two hundred men the truth is so
> Wrought in these Looms all in a row.

He also employed women and girls:

> And in a chamber close beside,
> Two hundred maidens did abide,
> In petticoats of Stammel red,
> And milk-white kerchers on their head,
> These pretty maids did never lin,[1]
> But in that place all day did spin.

William Stumpe, who is described by Leland as "an exceedingly rich clothier," actually proposed to use Malmesbury Priory as a workshop; and he undertook to employ two thousand workmen "continually in cloth-making."

Tuckar, a cloth-maker of Burford, in West Oxfordshire, employed five hundred of the "King's subjects" in carding, spinning, and weaving wool.

[1] Tire or slack.

Peter Blundell, of Tiverton, in Devonshire, bought kerseys in that region, took them to London, and sold them at a good profit. He afterward set up a factory business in his native town, amassed a considerable fortune, and founded the famous Free Grammar School at Tiverton, with which his name is associated.

The above examples are from the South Midlands and the West Country, which flourished exceedingly in Tudor times; there were also merchant clothiers at Bath, Bristol, Norwich, Halifax, Manchester, and Kendal. As one example, the name of Humphrey Chetham of Manchester comes immediately to mind.

It should not be overlooked that not only were the guilds opposed to the tendency toward centralization, but that the Government of the day looked askance at it. An Act of 1545 prohibited the erection and use of gig-mills; this was an Act intended to protect manual labour. The Weavers' Act of 1555 forbade clothiers who dwelt outside any corporate or market town to keep more than one wooden loom at a time in their houses, or to profit by the letting of looms. Another Act intended to curb the growing power of capital recited that no person was to hold more than two farms or to keep more than 2400 sheep. As a result of these Acts, and from other causes, the mercantile system retained a considerable measure of the domestic methods of the earlier guild system. Up to the time when Defoe toured the country the wool manufacture was still partly domestic and partly carried on in factories.

Daniel Defoe, in his *A Tour through England and Wales*, written in 1724–26, gives graphic descriptions of the mercantile-domestic system as he saw it in the Halifax district and at Leeds. In his second journey in the North of England he had gone from Rochdale over Blackstone Edge, and he approached Halifax from Sowerby Bridge and the upper valley of the Yorkshire Calder. He was much impressed by the density of the population in such a moorland district, and by the great number of houses in the valleys and on the lower hillsides. Some quotations from his book will not be out of place here.

> This is the reason also why we saw so few people without doors; but if we knock'd at the door of any of the master manufacturers, we presently saw a house full of lusty fellows, some at the dye-fat, some dressing the cloths, some in the loom, some one thing, some another, all hard at work, and full employed upon the manufacture, and all seeming to have sufficient business.[1]

Defoe also gives a graphic picture of the method of merchanting the finished cloth, as he saw it at the cloth market at Leeds. He writes:

> The cloth market . . . is indeed a prodigy of its kind, and is not to be equalled in the world. . . . The clothiers come early in the morning with their cloth; and . . . they go into the inns and publick-houses with it, and there set it down. At seven a clock in the morning, the clothiers being supposed to be all come by that time . . . the market bell rings; it would surprize a stranger to see in how few minutes, without hurry or noise, and not the least disorder, the whole market is fill'd; all the boards upon the tressels are covered with cloth, close to one another as the pieces can lie long ways by one another, and behind every piece of cloth, the clothier standing to sell it. . . .
>
> As soon as the bell has done ringing, the merchants and factors, and buyers of all sorts, come down . . . and walk up the rows, and down as their occasions direct. . . . When they see any cloths to their colours, or that suit their occasions, they reach over to the clothier and whisper, and in the fewest words imaginable the price is stated; one asks, the other bids; and 'tis agree, or not agree, in a moment. . . .
>
> By nine a clock the boards are taken down, the tressels are removed, and the street cleared, so that you see no market or goods any more than if there had been nothing to do; and this is done twice a week. By this quick return the clothiers are constantly supplied with money, their workmen are duly paid, and a prodigious sum circulates thro' the county every week.[2]

There were similar, but smaller, markets in many other towns; Exeter, Wakefield, and Halifax are specially named

[1] *A Tour through England and Wales*, by Daniel Defoe, vol. ii, p. 195 (Everyman's Library).

[2] *Ibid.*, vol. ii, pp. 204 *et seq.*

by Defoe. Piece-halls or cloth-halls were built in many towns, so that the sales could go on in any kind of weather. Bradford, Halifax, and Colne had piece-halls in the latter part of the eighteenth century.

FIG. 22. LOCATION OF THE WOOL INDUSTRY IN THE BRITISH ISLES

Single or scattered mills are not indicated.

N.B.—There is a far greater industry in the West Riding region—shown black—than in all the other regions added together. (See also Fig. 24.)

Up to this time the wool textile industry was carried on in every part of the country, some places and districts being more important than others. East Anglia, the West of England, Central Wales, East Lancashire, the West Riding, and the Border district of Scotland were the more famous regions. The West Riding began to go ahead early in the eighteenth

century, as the extracts from Defoe suggest; and the advance of the West Riding continued, until in the nineteenth it was easily supreme, though minor regions here and there retained some share of the industry. There even remained some traces of the former widespread character of the industry in the single, comparatively small mills which may still be seen dotted over the country.

The next revolution, or evolution, took place from about 1760 to 1840, as elaborate machinery took the place of the old-fashioned spinning-wheel and the hand-loom; as carding changed from a manual operation to a machine process, and as the wool-combing machine took the place of the old hand wool-comber. Most of the great inventions in the textile industries were made in the eighteenth century. They were taken up and improved by the cotton industry, as a rule, before the wool textile industry ventured on their use. A brief account of these great inventions will, therefore, be given in the chapters dealing with the cotton industry. The account in this book now passes on to the modern industry in wool, its present distribution in Britain, and the place it occupies in the national economy.

CHAPTER XIX

THE WOOL TEXTILE INDUSTRY: DISTRIBUTION AND SPECIALIZATION

THE wool textile industry of the British Isles is divided vertically into three sections—the worsted branch, the woollen branch, and the carpet trade; these sections use different grades of wool, and their processes are different. The raw wool itself is usually of three main classes—merino, crossbred, and low wool. Broadly speaking, merino and the finer crossbred wools are used by the worsted trade, the woollen branch uses the short fibre merino or crossbred wools, which have been rejected by the worsted trade, and the great reserve store which comes from woollen rags, and the lowest wools are used chiefly in the carpet trade.

The raw materials of the woollen trade thus include *mungo* and *shoddy*, which consist of the fibres obtained by 'pulling' good wool rags, tailor's clippings, stockings, and similar woollen fabrics. These recovered fibres go with the shorter fibres of original wools.

All wools at the outset must be carefully sorted, an operation which demands considerable skill and experience. A preliminary grading is often done in the wool-producing countries, especially Australia; this is known as classing the wool, and it obviates some of the sorting in the British wool trade. In all classing and sorting three grades of wool are aimed at—combing wools, for the worsted trade; carding wools, for the woollen trade; low wools, for the carpet trade. There are technical names for the different classes in the major grades, but these names need not be considered here.

All wools must go through the operation of scouring, which is a process for thorough cleaning and getting rid of excess grease. For successful scouring it is necessary to have a plentiful supply of soft and fairly pure water; water containing a large quantity of lime salts ('hard' water) is quite

unsuitable. A solution of good, soft soap is also necessary, and a mild alkali is sometimes added. The soft soap generally used is a specially prepared potash soap. The scouring process is a critical one, and needs care, skill, and experience. The soap solution must not be too strong, nor applied too hot, for in either case the wool would be left hard and brittle. After the scouring the wool often passes through technical processes of a preparatory nature, to tease out the fibres and to remove any bits of seeds, burrs, and other resistant vegetable matter which have survived the scouring process.

After the wool has been scoured and otherwise cleaned the next normal process is carding. The carding-machine is a complex machine with an arrangement of successive toothed rollers of different sizes, which revolve at different speeds. The wool is delivered at the end as a flimsy 'lap' of very loose texture, in which the fibres are more or less parallel. The light, flimsy lap is divided into narrow strips and a condensing machine makes these into thin bundles, or 'slivers,' each of which is an approximation to a thread, but which still needs more preparation before it becomes 'yarn.'

Worsted Yarns. From this point the two branches of the industry follow different lines. If the slivers are intended for the worsted trade they now pass to a combing-machine, whose task is to separate the long fibres, called 'tops,' from the short fibres, called 'noils.' The top is the long fibre delivered by the wool-comb; the noil is the short fibre removed by the wool-comb. The tops then pass through drawing-machines (which process may include from five to nine operations), and later still to the spinning-machine, which converts the worsted fibres into yarn. The worsted process begins really by rejecting short fibres of wool; then, when it reaches the yarn stage, a thread has been produced in which the constituent fibres are as uniform in diameter, length, and direction as possible.

The worsted then goes to processes preparatory to weaving, and then comes the all-important process which makes the cloth—viz., weaving. The principle of weaving is the same for worsted yarns, woollen yarns, cotton, and other fibres. In the worsted trade the usual devices are used for

producing variety of pattern, combinations of colour, and what is called 'finish'; these include arrangements of tappets, or cams for lifting the warp healds, complex fixtures called 'dobbies,' fixed over the loom, and the still more complicated arrangement of the Jacquard loom; such devices can only be understood fully after a practical acquaintance with looms. It is sufficient to state here that infinite variety of pattern, colour, and character of cloth is produced, and that new 'weaves' and adjustments are continually being thought out.

The dyer and the finisher receive the woven cloth and impart to it new colours, totally new characters of appearance and feel, and finally make it ready for the home or export warehouse.

The Woollen Branch. The woollen manufacturer begins with different grades of wool, and his aim is quite different from that of the worsted manufacturer. He starts with lower grades of wool, with shorter and less regular fibre; to these original wools he may add the noils rejected by the top-maker and the spinner in the worsted trade and the fibres from the rag-puller. Much finer counts of yarn are spun on the worsted principle than is possible on the woollen system. The woollen manufacturer aims, too, at a yarn in which the individual fibres are mixed in all directions, and in which the longer fibres support the shorter ones. There is no combing process, and the teasing which is done has quite another aim. The result of the preliminary operations and the spinning is that a woollen yarn is obtained which is not as strong as that obtained in the worsted process, but is far better for felting purposes. The minute serrations which are present on all wool-fibres help the latter to interlock, a result which is the aim of the later processes in the woollen manufacture. The woollen cloth is thus woven from warp and weft which are lighter, bulkier, and have high felting properties; a great variety of cloth is possible, and more varied effects may be produced.

The general arrangement of the two branches is shown by the diagram, Fig. 23, in which only the broadest outlines are indicated. There are many highly specialized inter-

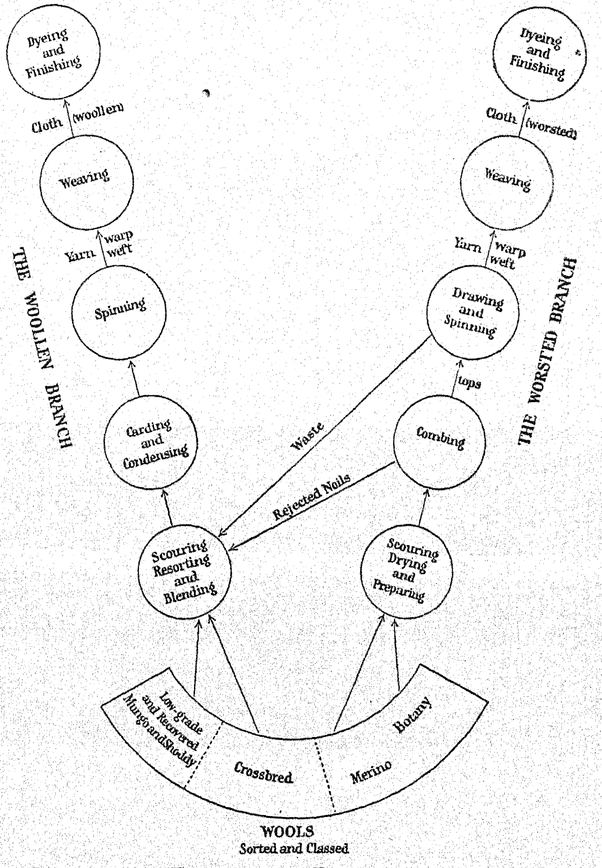


FIG. 23. AN ELEMENTARY DIAGRAM OF THE CHIEF PROCESS STAGES IN THE TWO BRANCHES OF THE WOOL INDUSTRY

There are many modifications of the stages. (The carpet industry is not included.)

With acknowledgments to J. A. Hunter's "Wool," in Pitman's "Common Commodities and Industries" series

mediate processes and stages at which an outsider can only look on and wonder. The carpet industry will be mentioned later. See p. 288.

Distribution of the Industry

In the woollen branch many firms carry on right through from wool to cloth, the whole of the processes being done in one mill, under one management.[1] In the worsted branch, however, there is much clear-cut specialization, many firms confining themselves to one group of operations, or even to one process. In Worrall's *Yorkshire Textile Industry*, under the heading "Bradford," for example, the classification is: (i) waste-pullers, wool-carbonizers, extractors and scourers; (ii) winders, warpers, beamers, etc.; (iii) wool-combers; (iv) worsted coatings, dress goods, etc., manufacturers; (v) worsted spinners and manufacturers. There is another group at the beginning of the Bradford list: bleachers, dyers, mercerizers, sizers, yarn-finishers, etc. The lists under (iv) and (v) are of great length. This shows somewhat the high degree of specialization that obtains in that home of the worsted trade.

Following the *Survey of the Textile Industries*,[2] the organization of the worsted branch may be summed up as follows: (*a*) Wool-buyers, generally known as wool merchants; these buy wool and resell to top-makers or combers. (*b*) Top-makers and combers; these blend wool as required for the production of the desired top, and comb it, separating the tops and noils. (*c*) Spinners; these convert the tops into yarn by the processes of drawing and spinning. (*d*) Warpers and sizers; these prepare the warps for weaving. (*e*) Manufacturers; these weave the yarn into the various fabrics. (*f*) Dyers and finishers.

Further variety is introduced into the wool textile industry by the use of other fibres than the wool of sheep; the chief are mohair, camels' hair, the wool or hair of the alpaca, the llama, and the vicuna; these are camel-like animals, natives of South America.[3] Cotton has long been used in many ways. Silk also, and now artificial silk is coming more and more into the industry. Some concrete examples of the use of

[1] Of course, this is not always the case.
[2] His Majesty's Stationery Office, 1928.
[3] The wool or hair of the llama is sometimes loosely grouped with 'alpaca.'

cotton and silk in conjunction with worsted may not be out of place. The writer, as a youth, worked in a mill which produced large quantities of what, in those days, were described as Bradford goods, although the town was in East Lancashire, near the county boundary, and the mill was described as a cotton-mill. He wove some thousands of yards of a cloth in which the warp was Egyptian cotton and the weft was a somewhat high-grade worsted. The weave was perfectly plain and simple. The cloth, after dyeing and finishing, was used for ladies' dresses. A year or two later, in another part of the same mill, he wove many thousands of yards of a somewhat coarser cloth, in Jacquard looms. Again the warp was cotton and the weft was worsted; and somewhat intricate patterns were produced in the cloth. A neighbour weaver in the same weaving-shed wove a cloth in a Jacquard loom of which the warp was real silk and the weft was very high-grade worsted. This cloth was intended for 'silk mufflers,' such as were quite commonly worn in those days—1877–81. The writer purchased one of these mufflers in 1878; it has been freely used, and after fifty years of wear it was still in good condition. The firm still exists, and in Worrall's *The Lancashire Textile Industry* it is described as making, among other things, "worsted stuffs in Jacquards." Goods of these and similar classes are extensively produced in the western part of the Yorkshire wool province to-day.

It has already been noticed that the wool textile industry has tended to become concentrated in certain districts; it has practically left East Anglia, where it was once very important. The village of Worstead, north-east of Norwich, gave its name to the worsted industry, which was for a time carried on extensively in Norwich; it is now almost confined to a limited region in the West Riding of Yorkshire.

The West Riding. The most important region of the wool textile industry in general is the West Riding, which possesses certain advantages of location. The early, more modern mills, were driven by water-power, and the West Riding possessed a great number of small streams which came down from the gritstone slopes of the Pennine moors; in the valleys

a great number of these small water-power mills grew up between about 1780 and 1820. After that came the coal era, the period of steam-driven and more complex machinery, and the attraction of coal soon made itself felt. Gradually the mills in the more remote Yorkshire dales, away from the coal, were given up, and the industry concentrated itself mainly on or near the western part of the rich Yorkshire coalfield. In this district there was abundance of soft, fairly pure water for scouring the wool (a very great advantage indeed) and for some of the other operations in the industry. The climate is rather humid, and the Yorkshire spinners say that this gives them a great advantage, especially in the spinning of crossbred yarns.

The wool textile industry of Yorkshire is confined to a very limited part of the West Riding, a region which is no larger than, say, Huntingdonshire, one of the smallest of the English counties. The Yorkshire region includes Leeds, Bradford, Halifax, Huddersfield, Dewsbury, Batley, Morley, Keighley, and a host of smaller towns and villages. The West Riding wool region does not reach beyond Wakefield, in the east, or Skipton, in the north-west;[1] and the cotton industry holds practically all that part of the West Riding which is close to the Lancashire boundary. The region is shown on the map, Fig. 24.

The predominant position of the West Riding region in the wool textile industry of Britain is sufficiently attested by the fact that out of 247,000 persons employed in the woollen and worsted branches in 1931 about 200,000, or slightly more than 80 per cent., were in the West Riding.

Within the Yorkshire wool manufacture there is considerable specialization in different parts; this is common knowledge in the region itself, and it may be clearly seen from a study of one of the directories of trades and firms. The worsted branch is located mainly in the valley of the middle Aire and its tributaries, and overlapping the watersheds a little on the north and the south. The chief towns are Bradford, Halifax, Shipley, Bingley, Keighley, Crosshills, and Otley. The region also includes the villages of the Worth

[1] Except that there is one worsted-spinning mill at Doncaster.

valley. The commonest entries in the directories are woolcombers, top-makers, worsted spinners and stuff manufacturers. Among the cloths produced in this worsted zone are linings for suits and overcoats, dress goods of many kinds for

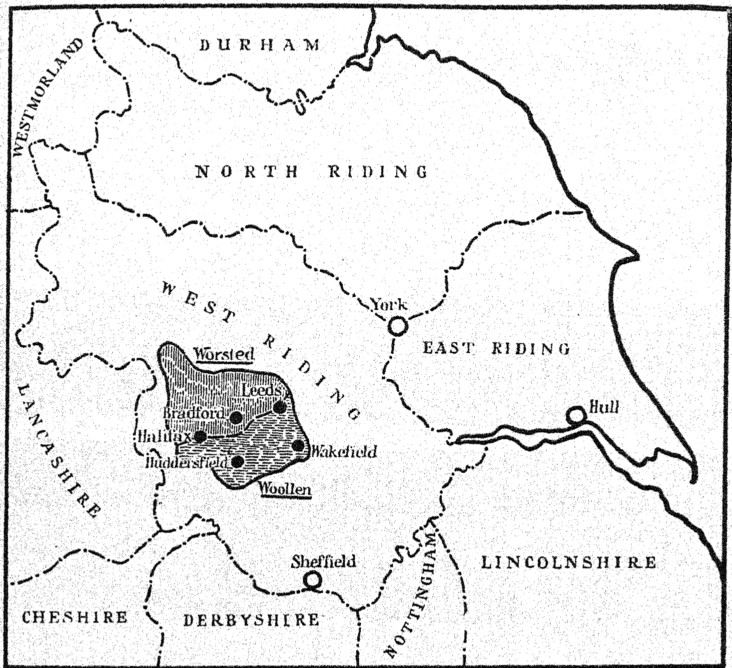


FIG. 24. THE REGION OF THE WEST RIDING WOOL INDUSTRY

The two branches, worsted and woollen, are broadly distributed, as shown by the different shadings in the diagram map.

ladies' wear, worsted coatings and suitings, and showerproof and waterproof cloths.

Bradford is the great market for the wool industry as a whole, but it is especially the headquarters of the worsted trade and the trade in mixed fabrics. The town still lives up to the character that Leland gave it in the sixteenth century, "a praty quik Market Toune. It standith much by clothing."

Leeds is common ground to the two branches; and in the directories one reads of both woollen and worsted spinners and manufacturers. Round about Leeds, and from Leeds south and south-west, is a zone which is mainly devoted to the woollen branch, including the mungo and shoddy pullers and manufacturers. This zone includes Morley, Batley, Dewsbury, and the upper part of the Colne valley. Here are produced felts, naps, beavers, and velours; flannels, blankets, shawls, and travelling-rugs; Army, Navy, police, and railway cloths; kerseys and wool serges; tweeds, sports tweeds, and plaids; and velvets for furnishing. At least one manufacturer advertises thus: "Speciality, rabbits' wool."

The division into the two main branches is quite well marked, but it is by no means absolute. There is considerable overlap in the upland region which lies between Leeds and Bradford. Also towns at the periphery or near it share in both trades. Leeds has been mentioned already; Huddersfield is somewhat similar; and Wakefield shows the same overlap, but on a much smaller scale, as this is almost the eastern limit of the wool industry of the West Riding. In Huddersfield rag-pullers, waste-pullers, mungo and shoddy manufacturers, hearthrug manufacturers, woollen-spinners, and angola-spinners—all indicating the woollen branch—carry on their business cheek by jowl with worsted-spinners and those who carry on both the woollen and worsted branches. High-class worsteds and 'fancy worsteds' are made in the Huddersfield district, and there are both fine woollens and cheap woollens produced.[1]

As to the number of people engaged in the two branches, the census of 1921 shows that for that year the woollen branch claimed 94,578, while the worsted branch found employment for 112,376; these figures are roughly in the proportion of four to five.

The Scottish Border. The region which stands next to the West Riding in the number of persons employed is the Border region of Scotland, chiefly in the counties of Roxburgh, Sel-

[1] Note also the West Riding carpet manufacture mentioned in Chapter XXIV.

kirk, and Peebles, overlapping into Berwick on the north-east and Dumfries on the south-west. Here about 8500 people were employed in 1931; the chief centres are Hawick, Galashiels, and Selkirk. The district makes Scottish 'tweeds,' fine woollens, cheviots, sports wear, underwear, high-grade hosiery, and blankets. In this region the woollen manufactures of Ayrshire may also be included, the chief places in that county being Kilmarnock, Stewarton, Ayr, Dalry, and Galston. Here are produced Scots bonnets, tam-o'-shanters, aviator's caps, knitted scarves and coats. The "West of Scotland Home Industries" at Girvan makes "cottage-made hand-loom tweeds."

The word 'tweed' as the name of a cloth deserves mention at this point. The name is applied to a kind of woollen cloth which has a twilled weave; it is a twilled cloth of various patterns, widely used for men's suits. The manufacture of these cloths grew up in the Tweed valley, and it is said that a mistaken reading of an invoice made the technical word 'twill' into 'tweed,' and the name has stuck to these cloths ever since.

The Scottish Border makes very high class goods generally and constitutes an important region of the wool industry. In the early days of the industry the district depended upon the plentiful water-power of the southern uplands. Now coal is imported by easy routes from the Midlothian Coalfield and the industry maintains its ground.

The reader may be reminded that some of the counties mentioned above have the largest proportion of sheep to acreage in the British Isles; the sheep, however, are largely of the Black-faced Mountain and Cheviot breeds, and the wool is somewhat coarse, and not adapted for the fine woollen goods for which the district is famous. The mills depend largely upon imported wool.

East Lancashire. The region which comes next in importance to the Scottish Border is East Lancashire, where 8500 persons were entered on the census sheets of 1931 as employed in the woollen and worsted industries; the actual work done is almost entirely in the woollen branch. None of the towns mentioned below, however, is fully engaged

in wool; the cotton industry completely overshadows the older industry in this region. The chief towns which are partly engaged in the wool textile industry, or which have one or more mills, are Rochdale (a famous and ancient centre of the trade), Bury, Heywood, Mossley, Royton, Littleborough, and Ramsbottom. There is a considerable felt industry in Rossendale, where felt slippers are made in large quantities. The chief woollen goods in the region generally are flannels, blankets, felting cloths, and billiard cloths.

The "West of England." Another region of considerable extent, and of great historic interest, is the one which is loosely called the "West of England," or the "West Country." The industry is scattered through the counties of Gloucestershire, North-west Oxfordshire, North Wiltshire, and Somersetshire; and it includes towns as far apart as Chipping Norton, in the north, and Wellington, in the south-west. The region is relatively but a shadow of its former self, but it is still celebrated for certain classes of woollen and worsted goods. The woollen branch predominates decidedly. Some of the specialities of the district include riding tweeds, whipcords, various livery, Navy, Army, and sporting cloths, blankets, rugs, felts, and flocks.

The chief towns are Stroud, in Gloucestershire, which has both worsted and woollen manufactures, Trowbridge, in Wiltshire, also with a varied trade, and Witney, in Oxfordshire, which specializes in blankets. The total number of workers engaged in 1931 was about 4000.

Wales. Wales is a somewhat peculiar example. It was long the case that mid-Wales was described as a woollen region of some importance; but that is no longer true. There are few woollen-mills now in the East Montgomery district, where there were quite a number at one time. A statement in the report of the departmental committee appointed by the Board of Trade issued in 1918 reads "and flannels are also produced at Dolgelly and Welshpool, in Wales"; in the *Survey of the Textile Industries*, published in 1928, the statement is repeated. There is, however, no mention of a flannel-mill in either Dolgelly or Welshpool in Worrall's *British and Dominion Textile Industry*, and the *Official Guide* for

Welshpool tells that the ancient industry of flannel-weaving has decayed and almost disappeared.

There are woollen-mills, most of them very small, scattered here and there in every Welsh county; the most important places are Henllan, in Cardiganshire, Carmarthen, Drefach-Henllan, and Llanbyther, in Carmarthenshire, Llandyssil, on the borders of the two counties mentioned, Llanidloes and Newtown, in Montgomeryshire. The number of people employed is now very small.

Leicestershire. The remaining region in England where there is a considerable industry in worsteds and woollens is Leicestershire. Some thousands of people are employed in these branches, chiefly in the production of yarn for hosiery and underwear, and in worsted-spinning. In a recent issue of Worrall's directory the names of seven firms were given as wool- and worsted-spinners in Leicester alone; several of them are producers of 'hosiery yarns.' Leicester has also a long list of hosiery manufacturers; but they do not restrict themselves to woollen or worsted yarns by any means; silk, artificial silk, and cotton are all called upon. Nor do they confine themselves to 'hose' in the narrow sense; all kinds of underwear, sports coats, blouses, jumpers, football jerseys, sweaters, scarves, and bathing-costumes come within their scope.

Leicester is the leading centre, but the industry spreads to Loughborough, Hinckley, Melton Mowbray, Wigston, and into the adjacent counties. The subject will come up again when the hosiery of the Midland textile province is discussed, in Chapter XXV.

Other Sites in England. Scattered here and there in England and Wales are single factories or small groups engaged in the woollen or the worsted trade, usually the former. Carlisle, Kendal, Darlington, Coventry, Nuneaton, Norwich, and Buckfastleigh, in Devon, may be mentioned as examples. In the whole of the eastern coastal counties, from the Humber to the Thames, there would seem to be only three small woollen or worsted factories. This fact represents one of the greatest changes in the location of British industries compared with, say, two hundred years ago.

Scotland. In Scotland there are woollen-mills scattered over many counties, in addition to the Border region and Ayrshire, which have been mentioned already. In Glasgow and Paisley and the immediate district many manufacturers are described as "cotton and woollen goods manufacturers"; there are also a number of hosiery-makers.

There is a region which stretches from the neighbourhood of Stirling, through Alloa, to Kinross. This little province turns its attention to shawls, mufflers, tweeds, hosiery, and blankets. Alloa and Tillicoultry are the more important centres, but the names of Stirling and historic Bannockburn should not be overlooked.

In the far south-west of Scotland there are two mills listed at both Newton Stewart and Kirkcowan, while in Aberdeenshire there are woollen industries at Aberdeen, Woodside, Huntly, and elsewhere. During the seventeenth and eighteenth centuries Aberdeen was famous for its imports of wool. Elgin and Forres, in Moray, and Inverness, at the northern end of the Great Glen, have each two factories. Finally, across the North Minch, at Stornoway, there are two mills which make Harris and Lewis tweeds and Shetland homespuns. The hand-weavers of the Shetlands (Fair Isle particularly) and of the Hebrides produce cloths which have now a widespread reputation.

In *Northern Ireland* there is a scattered woollen industry, the principal articles produced being tweeds, suitings, overcoatings, blankets, and rugs. Ballymena, Belfast, and Newtownards are the more important centres. The Caledon woollen-mills, in County Tyrone, may be taken as a type of the single mill in a rather wide region; there are made "all classes of woollens suitable for men's and ladies' wear—saxonies, cheviots, worsteds, homespuns, donegals . . . [and] travelling-rugs in all the latest checks and art shades."[1]

In *Éire* (the former Free State) the woollen industry is widely scattered also, the more important centres at the present time being Cork, Dublin, Glenties, Kenmare, Kilkenny, Athlone, and Tralee. The goods produced include

[1] It was announced in December 1929 that these mills were closing down for a time, owing to bad trade.

Irish tweeds, homespuns, worsted suitings, friezes, Irish kerseys, rugs, shawls, flannels, and blankets.

There are five factories scattered through the *Isle of Man.*

The Supply of Raw Material

It is obvious enough that a plentiful and cheap supply of raw material is essential for such a highly organized, scattered, and yet locally concentrated industry. The British Isles could well deal with an assured import of 800,000,000 lb. of sheep's and lamb's wool, in addition to the share of home-grown wool that it retains, and the mohair, alpaca, etc. The home clip varies from about 52,000,000 lb. to 95,000,000 lb., the average for four recent years being about 71,000,000 lb. Some wool is also obtained by the fell-mongers from sheep-skins imported into the British Isles; this additional supply generally amounts to between 15,000,000 lb. and 25,000,000 lb. for a year.

There is a considerable export of wool from Britain, both of the home clip and of merino, for example, from Australia, and of crossbred wool which has been imported from New Zealand. In 1935 the position worked out as follows, in round figures:

Imported wool and mohair .	597,000,000 lb.
Home clip	120,000,000 lb.
Wool from imported skins .	16,000,000 lb.
Shoddy, etc.	104,000,000 lb.

This makes a grand total of 837,000,000 lb.; the export of home-clip wool of all kinds was 55,000,000 lb., leaving an apparent quantity for home use of 782,000,000 lb. This is less by nearly 100,000,000 lb. than the average amount available in the early years of this century. The position would be such as to cause anxiety if consumption were normal; but cheaper wool is a great desideratum.

Speaking generally, Britain purchases wool from Australia, New Zealand, South Africa, the Argentine and Uruguay, and smaller amounts from other sources. She is a large buyer of crossbred wools, a considerable buyer of merino, but only a slight buyer of low wools. The British ports which receive

the wool are London, which in 1935 received 40 per cent. of the total imports, Hull, 20 per cent., and Liverpool, 25 per cent. The remainder came chiefly to Southampton, Bristol, Manchester, and Goole.

The value of the domestic exports of woollen and worsted yarns and manufactures was £32,214,000 in 1936 and £35,486,000 in 1937; these values represent 7·2 per cent. and 6·7 per cent. respectively of the total export of articles wholly or partly manufactured. The chief buyers are Canada, Australia, Japan, China, Germany, the Argentine, India, New Zealand, and South Africa. A satisfactory feature is the prominent position occupied by the British Dominions.

CHAPTER XX

THE COTTON INDUSTRY: ITS HISTORY IN BRITAIN

The cotton industry in Britain has not the long history of the woollen industry, of which it may be regarded as the child. Two hundred years ago it still occupied an obscure place compared with its parent; but it outstripped the latter a little more than a hundred years ago, and it is now the largest manufacturing industry in Britain and the largest textile industry in the world. In the number of people employed, in the amount of capital invested, in the value of its output, in the share that it contributes to British exports, and in its international position it is without serious rival.

It is not known when cotton was first worked in the British Isles. Cotton was certainly being imported, irregularly and in small quantities, in the fourteenth, fifteenth, and early sixteenth centuries; but there is little evidence of any systematic use of cotton in the manufacture of English cloths before about 1600. There are several indications in the records for the years from 1550 to 1600 that cotton was gradually creeping in, and after that time the "bombazene Cotton such as groweth in the land of Persia being no kind of wool" was used more openly. In 1605 it is recorded that at London "strangers of the Wallon congregation doe this daye present a cloth of new device called sattin cotton or bumbazie, made part of sylke and part of cotton woll."

In the seventeenth century the use of cotton was certainly increasing in Lancashire, and already its use was frequently mentioned as being particularly connected with that county. A London official complained in 1613 of "bastard perpetuanas made of says milled, Manchester or Lancashire plains, in form of kersies, to the discredit of those sorts of goods." It was stated in a petition to Parliament in 1621 that "diverse

people in this kingdom, but chiefly in the county of Lancaster, have found out the trade of making of the fustians, made of a kind of bombast or down, being a fruit of the earth growing upon little shrubs or bushes, brought into this kingdom by the Turkey merchants, from Smyrna, Cyprus, Acra, and Sydon, but commonly called cotton-wool."

Cotton was obviously being increasingly used, although in some of the older centres of manufacture it was regarded somewhat in the light of a fraudulent substitute for the recognized fibres—wool, silk, and linen. The progress of cotton in Lancashire seems to be attested beyond all doubt by Lewes Roberts, Merchant and Captain of the City of London, who wrote in 1641:

> The towne of Manchester in Lancashire must be also herein remembered, and worthily for their encouragement commended, who buy the yarne of the Irish in great quantity, and weaving it returne the same againe in Linen into Ireland to sell; neither doth the industry rest here, for they buy cotton woole in London, that comes first from Cyprus and Smyrna, and at home worke the same, and perfit it into fustians, vermillions, dymities, and other such stuffes.

These quotations would seem to prove that 'cotton-wool' was becoming a more regular import into Britain, and that Lancashire was already beginning to specialize in its manufacture. A quotation from Fuller, written in 1662, clinches the argument. He is writing of the fustians which had long been made at Augsburg, Jena, and Milan, but which were now made in Lancashire. He writes:

> These retain their old names at this day, though these several sorts are made in this country, whose inhabitants, buying the cotton wool or yarne, coming from beyond the sea, make it here into fustians. . . . Bolton is the staple place for this commodity.

Until about 1770 cloth rarely seems to have been made of cotton only. Defoe, from whose *A Tour through England and Wales* quotations have already been made concerning the wool manufacture, mentions that Manchester was making "a kind of cloth called fustians, partly out of cotton wool from

Smyrna and the Levant and partly out of linen and even wool." John Dyer, whose famous poem *The Fleece* appeared in 1757, adds a most interesting note explaining one of his lines: "There is woven at Manchester, for the East Indies, a very thin stuff of thread and cotton, which is cooler than the manufactures of that country, where the material is only cotton."

The "Manchester Act" of 1736 imposed heavy duties on calicoes made exclusively of cotton, in order to protect the wool and linen interests. Indeed, it is very doubtful if even Lancashire made fabrics of cotton only, at least to any great extent, until about 1770. The Act of 1774 legalized the manufacture of cloth made entirely of cotton; but Arkwright had almost certainly been making calicoes with cotton warp and cotton weft for some little time before that Act. So long as the weaver in Britain depended upon domestic spinning he could not get cotton yarn suitable for warp, although this was obviously common enough in India, and probably so in some parts of the Continent. Cotton came into its own with the inventions of Hargreaves and Arkwright and Crompton.

The cotton industry had been making slow but definite progress from about 1600; in about 1770 it began to go ahead at an amazing rate, and by 1820 it had surpassed the older, parent industry. This was in consequence of the invention of new machines and the adoption of new processes in the textile industries, and at the same time was due to the improvement of the steam-engine and new methods of making iron and steel. Again, between 1750 and 1820—and this, be it noted, is before the railway era—there had been great improvements in the means of transport, by river, canal, and road. The inventions and improvements marched together and acted and reacted upon each other.

Inventions in Spinning and Weaving

The great inventions which revolutionized the textile industry were made in that marvellous sixty years from 1730 to 1790. They began with the invention of the 'fly-shuttle' by John Kay, of Walmersley, a little village near

Bury, in Lancashire. Instead of sending the shuttle through the warp-shed by hand directly, he made a mechanical device

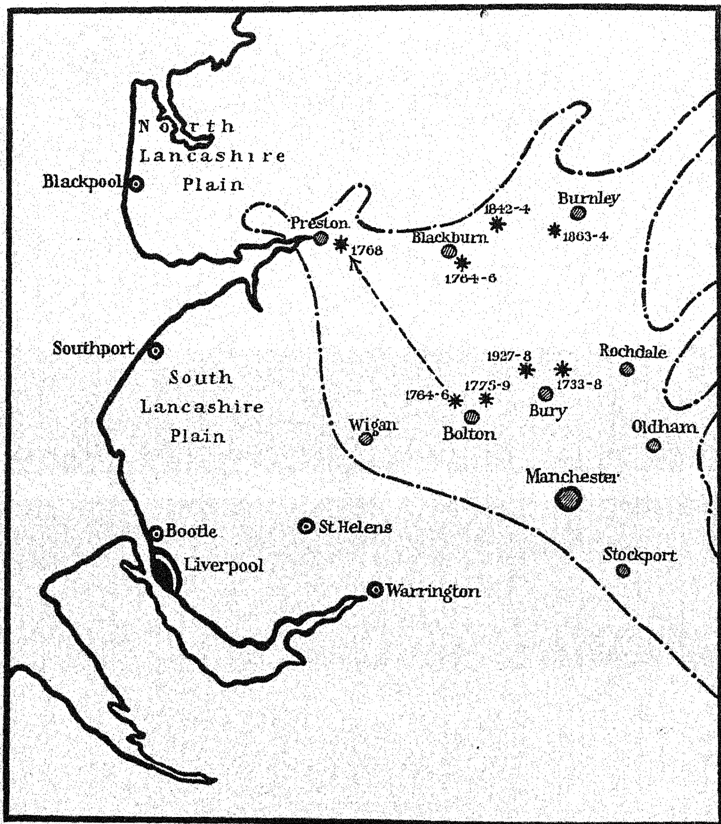


Fig. 25. Where the More Important Discoveries and Inventions in connexion with the Lancashire Textile Industry were made

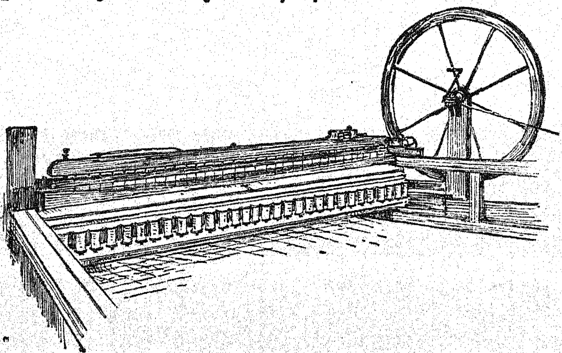
The cotton and mixed textile industry of South-east Lancashire is almost entirely confined within the boundary line shown on the diagram map.

which was the forerunner of the modern picking-stick and picking-band. It was now possible to weave about twice as fast and to weave a much wider cloth without calling upon

two people to throw the shuttle across the shed to each other. Kay's invention was made and developed between 1733 and 1738.

Robert Kay, the son of John Kay, invented the drop-box for shuttles in 1760. It was possible by means of this invention to use a succession of shuttles, each with a differently coloured weft, without the delay of stopping the loom to change the bobbin in the shuttle.

James Hargreaves of Blackburn invented the spinning-jenny, probably in the year 1764. He conceived the idea of



HARGREAVES' SPINNING-JENNY (ABOUT 1768–70)

making a wheel drive a number of spindles, and the necessary action of drawing the wool or cotton (which had been done by hand) was performed by a movable carriage through which the 'rovings' passed before they came to the spindles. In this machine the threads were made more even than they had been by hand; and by using eight spindles he produced eight times the amount of yarn. The number of spindles did not stop at eight, and by the time he took out his patent in 1770 about sixteen spindles were being worked on one machine; and later many more were added.

Meanwhile Richard Arkwright, who was born at Preston, and later lived at Bolton, was working at a totally different idea for machine-spinning. Arkwright set up his first machine in 1768. He made the rovings pass through rollers, revolving at different velocities on their way to the spindles. The

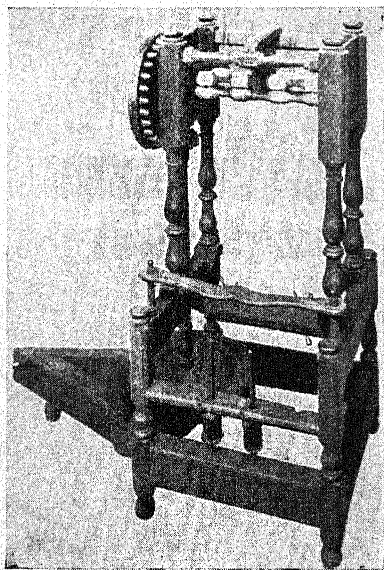
rollers drew out the rovings, and the revolving spindles gave the necessary twist. The spinning-jenny of Hargreaves could spin only weft yarn; Arkwright's machine could spin twist yarn or warp yarn; and Arkwright's yarn was more even in thickness and regular in twist.

There has been much controversy about the originality of Arkwright's inventions. Thus the *Handbook to Birmingham* prepared for the meeting of the British Association in 1913 states that a method similar in principle to Arkwright's had been invented in Birmingham by either John Wyatt or Lewis Paul, thirty years before Arkwright's invention. Others have asserted that Arkwright took his ideas from Thomas Hughs, a reed-maker of Leigh, or from Kay, a clock-maker of the same town. One thing is, however, certain; Arkwright was the first to make rollers work satisfactorily.

SIR RICHARD ARKWRIGHT

A third great inventor was Samuel Crompton, who was born at Firwood, near Bolton, in 1753, and who afterward lived at Hall-i'-th'-Wood at Bolton. Like many men in those early days, he learned both spinning and weaving. He was about twenty-one years old when he started to make a better machine than the one he was using—Hargreaves' 'jenny.' The machine which he invented combined the principles of the machines of Hargreaves and Arkwright. He made one special and important addition, however; this was a spindle carriage. In the 'jenny' of Hargreaves and the 'water-frame' of Arkwright the spindles were stationary; in Crompton's machine they were erected on a movable carriage which ran on wheels. This is "the great and important invention of Crompton," to quote his biographer and friend, John Kennedy. It was no doubt because of the combination of the two principles that Crompton's machine was afterward called the 'mule,' a name by which it is known to this day.

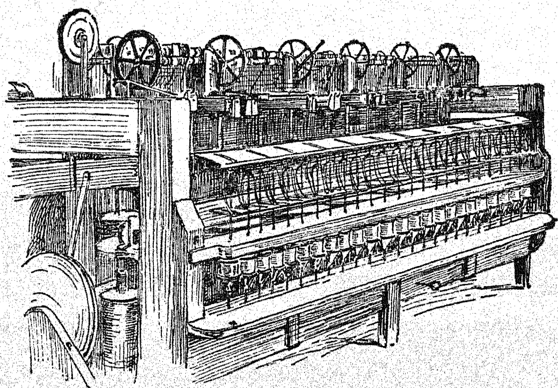
Crompton's invention enlarged the scope of the spinner. Hargreaves' 'jenny' would make only rather poor weft yarn; Arkwright's machine made stronger yarn, fitted for warps. Crompton's machine would spin finer thread than either of the others, and it was suited for both warp and weft. Arkwright's 'water-frame' and Crompton's 'mule' were the prototypes from which the marvellously effective machines of to-day are descended. Spinning machinery at the present day is mainly of two types; the ring-frame, which has been evolved from Arkwright's machine, and the modern self-acting mule, which is the descendant of Crompton's first machine. Many men have contributed important improvements to the machines. The most important in the case of the mule was the work of Richard Roberts, who in 1825 invented a device to make it self-acting, or automatic.



ARKWRIGHT'S SPINNING-FRAME (ABOUT 1769)

When Kay was working at his flying-shuttle, nearly fifty years before the date of Crompton's invention, the weaver had often to wait a good deal for the spinner; Kay's invention emphasized the inequality. For thirty years the loom could far outrun the spindle, and the weaver was much at the mercy of the spinner. The inventions of Hargreaves, Arkwright, and Crompton reversed the position; it was now the loom that lagged behind, and there was need of a mechanically driven loom. Edmund Cartwright, a clergyman who held a living in Leicestershire, turned his attention to the problem in 1784, and in 1785 took out his first patent.

He continued his work, and in 1787 he made a loom which included the general principles of the modern loom; the three essential motions of the loom—shedding, picking, and beating up—were done by mechanical contrivances instead of by the hands and feet of the weaver. Out of Cartwright's crude loom the modern highly efficient loom has been evolved; and although the essential principle remains the same improvements are being continually added.



ARKWRIGHT'S WATER-FRAME

By about the year 1790 the first great cycle of textile inventions was complete; Kay, Hargreaves, Arkwright, Crompton, and Cartwright had done that which was calculated to revolutionize the textile industries, and in course of time to make the cotton industry what it is to-day, the greatest single textile industry in the world.

It will be noticed that four of these inventors were Lancashire men, and did most of their work in that limited region in which lie Bury, Bolton, Blackburn, and Preston. These towns are in the region in which the manufacture of woollens and mixed goods was already well established, and where cotton had apparently received more sympathetic attention than in the other textile regions. Cartwright was a Nottinghamshire man who had received his early education at Wakefield Grammar School, before he went up to Oxford.

He set up a small factory at Doncaster, where he proposed to carry on his experiments in spinning and weaving; but after several set-backs to his projects his resources became exhausted, and the mill was closed. Meanwhile the loom was being tentatively taken up by Manchester cotton manufacturers; and though one of the earliest mills where the new mechanical looms were being used was burned down, the manu-

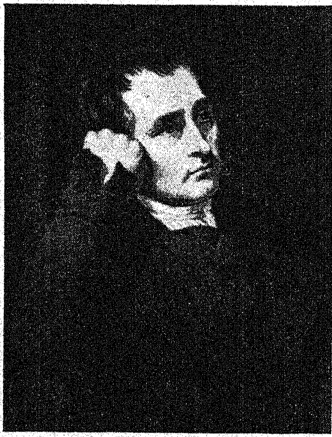
HALL-I'-TH'-WOOD, BOLTON

From "The Romance of the Cotton Industry in England" (Oxford University Press)

facturers saw great possibilities in it. William Radcliffe, John Horrocks, Richard Roberts, and Thomas Johnson improved on the early crude loom, and out of it the modern Lancashire power-loom was evolved. It had come into fairly general use in Lancashire soon after the end of the Napoleonic wars.

Lancashire had now taken hold of the cotton industry; spinning and weaving had become mechanical; the machines of Arkwright and Crompton more especially encouraged the development of the big factory; the steam-engines of Boulton and Watt were applied in increasing numbers from 1790 onward; and by 1815–20 the mercantile system was practically at an end except in remote regions. It had given place to the modern factory system.

The inventions which have been mentioned in merest outline in the preceding pages were concerned with the major processes, spinning and weaving. There are many subsidiary processes which play an important part in the cotton industry. Some of these are directed to preparing the raw cotton for the spinning process, and include elaborate machines for bale-breaking, cotton-opening, scutching, carding, combing, drawing, and roving. Many minds have given their attention to these machines, Arkwright and Cartwright among the number. Between the spinning and weaving come winding, warping, and sizing, and here again there has been room for much inventive skill.

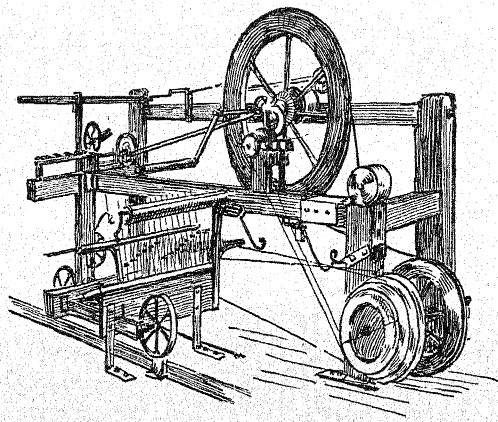


SAMUEL CROMPTON

These various contrivances were taken up much more keenly in some parts of the country than in others. As a rule, the world does not take kindly to a real, fundamental change, especially to one which changes the routine of people's lives and which upsets previous ideas. Norwich, where textile manufactures had been going on for centuries, did not take kindly to the later inventions, just as the weavers of Colchester had refused to work Kay's flying-shuttle half a century earlier. It was not altogether for the same reason that the textile industry of the West Riding did not take up the new invention as quickly as did the cotton industry. The power-loom was adopted far more readily by the worsted branch than by the woollen branch. The softer yarns used in the latter would not stand the strain involved in the more rapidly working power-loom; hence the hand-loom maintained its ground for some time. Similarly hand-spinning maintained its ground longer in Yorkshire than in Lancashire.

Combing was regarded as more important in the wool trade

than in the cotton trade, though in the case of finer counts[1] of cotton the slivers pass through a combing-machine to ensure perfect parallelism of the fibres and the removal of the shorter and broken ones. The inventors succeeded only in producing satisfactory wool-combing machines in the middle of the nineteenth century. Josué Heilmann, in Alsace, produced his machine in 1848, an invention now widely used on the Continent and in the cotton trade of Britain. Isaac Holden, a Scotsman who came into the Bradford district as a young man, and eventually built up a big business, worked in conjunction with Samuel Cunliffe Lister, a Yorkshireman, and invented a successful machine in 1851, and James Noble in 1853 invented the wool-combing machine which is now most widely used in England. John W. Nasmith of Manchester, produced another machine which is widely used in the English cotton trade.



CROMPTON'S SPINNING-MULE

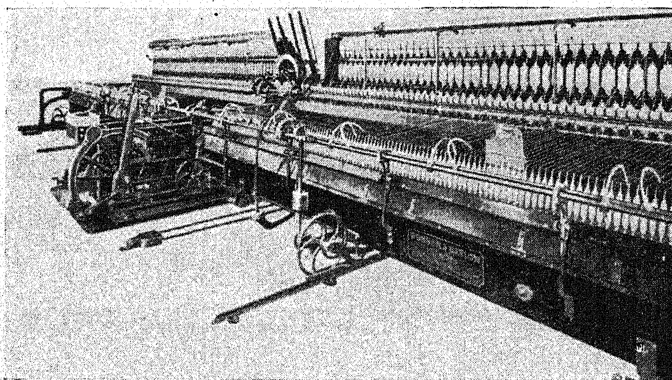
The 'carrier' is seen on the left of the machine.

To come back to the early development of the cotton industry; it should not be imagined that the adoption of the inventions of Arkwright, Crompton, and Cartwright meant the *sudden* passing of the mercantile or domestic system and the coming in of the modern large factory at once. There was an evolution of the factory. It has been noted already that men such as Jack of Newbury employed what were for those days great numbers of men, women, and children in factories. Humphrey Chetham owned factories in

[1] 'Counts' is a term used to indicate the thickness of a yarn.

Manchester and other parts of Lancashire in the seventeenth century; John Harrison of Leeds was also a large employer about the same time. In the petition that led to the passing of the "Manchester Act" of 1736 there is mention of employers who employed two or three thousand workers, many of whom did their work in factories, though many still worked in their own homes, for the 'merchant.'

Nor was the beginning of the modern factory wholly coincident with the coming of steam-power. Water-power had



A Modern Mule Spinning-machine

long been used in certain branches of the cotton industry, and it continued to be used until the middle of the nineteenth century, even to drive the machinery of the great inventors. The use of fulling-mills instead of hand and foot had raised great opposition among workers ever since the Middle Ages. This opposition, which was continued for many centuries, was no doubt the chief cause of the slow growth of machinery. To pass over many centuries to the beginnings of modern times, Arkwright in 1768 or 1769 joined forces with Jedediah Strutt of Nottingham, an inventor as keen and able as himself, and they built a mill at Cromford, in Derbyshire, to take advantage of a reliable stream of warm water fed from a lead-mine drain in the hillside. It was probably from this that Arkwright's machine came to be known as the 'water-

frame' and the yarn he produced to be spoken of as 'water-twist.' It is stated that not until 1790 was Crompton's machine worked by water-power. From about 1775 there sprang up in many parts of the country little water-mills, especially among the hilly districts of the Pennines. Scores of these early cotton-mills and woollen-mills can still be traced in East Lancashire and the West Riding of Yorkshire.

JEDEDIAH STRUTT
J. Wright.
By courtesy of the English Sewing Cotton Co., Ltd.

Steam-power seems to have been introduced about 1780, and in 1781 Matthew Boulton wrote to James Watt, his partner, that "the people in Manchester are all steam-mill mad." The new power only came into use gradually, for it was not until between 1810 and 1820 that it was first widely used in some of the Pennine valleys. A steam-engine was set up at Lomeshaye (the modern Nelson) about 1795. The factory workers still spoke of 'steam-looms' when the present writer went to work as a 'half-timer' in a Lancashire cotton-mill in 1871.

The domestic worker persisted in the more remote districts right on until 1850–60. The paternal grandfather of the writer was a woolcomber, the 'kammer' in the hillside village where he lived. He worked at home, and was considered a skilled workman at that particular occupation. That phase of domestic occupation seems to have come quite to an end in his district about 1850, possibly in part because cotton was displacing worsted in those hillside villages on the Lancashire-Yorkshire border, and partly because of the wool-combing machines, which were then attaining to modern

perfection. Cotton had driven out wool in that district; machinery had displaced manual combing, spinning, and weaving, though in rare instances old men and women were still using their spinning-wheel, their bobbin-wheel, or their hand-loom, to the writer's knowledge, in 1880–90.

It may be permissible in this brief summary of history to glance at one of the social consequences of this period of transition. Men had reached, say, an age of forty years or more, had followed only one occupation, and had seldom left their village or small town. It was not easy for them to obtain a new job, and it would not have been easy for them to master it if one had been open to them. There was often much suffering. When the writer's father was a boy his father lost his job, at which he was an expert. For some years the food of the large family consisted of oatmeal porridge and 'blue' milk, twenty-one times a week—if resources would run to that length. Bread and treacle was a very great luxury; meat was practically unknown, except on the rare occasions when a kindly neighbouring farmer killed a pig. And yet some people are surprised that there should be a heritage of distrust between the employing and employed classes in many such districts! Memories of those hungry days died hard among those who had experienced them.

CHAPTER XXI

THE BRITISH COTTON INDUSTRY: SPECIALIZATION AND LOCALIZATION

It has been noted that the cotton industry was definitely established in East Lancashire and the immediate neighbourhood by the dawn of the nineteenth century; but neither in its present form, nor with its present boundaries. Burnley, for example, is essentially a typical Lancashire cotton town to-day; but it was described as a worsted town up to about 1820. The wool trade has there been completely replaced by the cotton trade since those early days.

For the most part the pioneer employers engaged in the two main processes of spinning and weaving;[1] and these processes were often carried on under the same roof or in the same group of buildings. Early in the nineteenth century spinning and weaving frequently began to separate, and many big cotton firms confined themselves to one of the chief branches of the industry. There are some of the older firms who still carry on spinning and weaving, but this is not now the common practice. Towns and districts also show clearly the tendency toward specialization. The modern Nelson, a town of 40,000 people, is essentially a weaving town; the only spinning carried on there is a limited amount of 'doubling,' which requires cotton that has been spun once already. In the town there are about 53,000 looms and 24,000 doubling-spindles. On the other hand, the town of Mossley, in South-east Lancashire, does comparatively little weaving, and so far as the cotton trade is concerned almost confines its activities to spinning; in the town there are about 1,400,000 spindles and 1000 looms. Similarly in the case of some of the bigger cotton towns of Lancashire: Burnley weaves much and spins little and "Greater Burnley" has about 101,000 looms, but only 560,000 spindles; Oldham

[1] Employers of weavers are usually called manufacturers in Lancashire.

spins much and weaves little, and "Greater Oldham" has about 17,400,000 spindles and only 12,000 looms. These proportions may be put more effectively by taking 100,000 spindles as a unit in spinning, and 1000 looms as a unit in weaving. On the basis of these units the spindles and the looms in the following four towns are:

	Spindles	*Looms*
Burnley	5·6	101
Nelson	0·24	53
Oldham	174	12
Mossley	14	1

The spinning industry, with its attendant sub-processes, is carried on mainly in South-east Lancashire, within a dozen miles of Manchester. Here are many towns arranged in a crescentic curve round the great centre of the industry—Manchester; the towns are Stockport, Ashton, Mossley, Dukinfield, Stalybridge, Oldham, Royton, Rochdale, Heywood, Middleton, Bury, Bolton, Wigan, and Leigh. These towns are essentially spinning towns, and here are located about 80 per cent. of the spindles of the Manchester province. There is some spinning carried on at Huddersfield, Halifax, Todmorden, Colne, Clitheroe, Burnley, Accrington, Blackburn, Darwen, Chorley, and Preston, but probably not more than 18 per cent. of the spindles are located so far from Manchester.

The main weaving zone lies farther afield from the centre of the industry, chiefly north of the Rossendale Fells. Here, in the valleys of the Ribble and its tributaries, the Lancashire Calder, the Darwen, and the Douglas, are the chief weaving towns: Colne, Nelson, Burnley, Accrington, Padiham, Great Harwood, Clitheroe, Blackburn, Darwen, Chorley, and Preston. There the weaving far outweighs the spinning, and from 75 per cent. to 80 per cent. of the looms of the Manchester province are located in this zone. The towns mentioned are all in Lancashire. In the north-east this weaving zone extends into the West Riding, beyond Colne. Here are Barnoldswick, Earby, Skipton, and a number of villages. Barnoldswick and Earby confine themselves to the cotton

industry, and Skipton has more cotton-mills than worsted-mills. These West Riding towns are engaged in weaving far

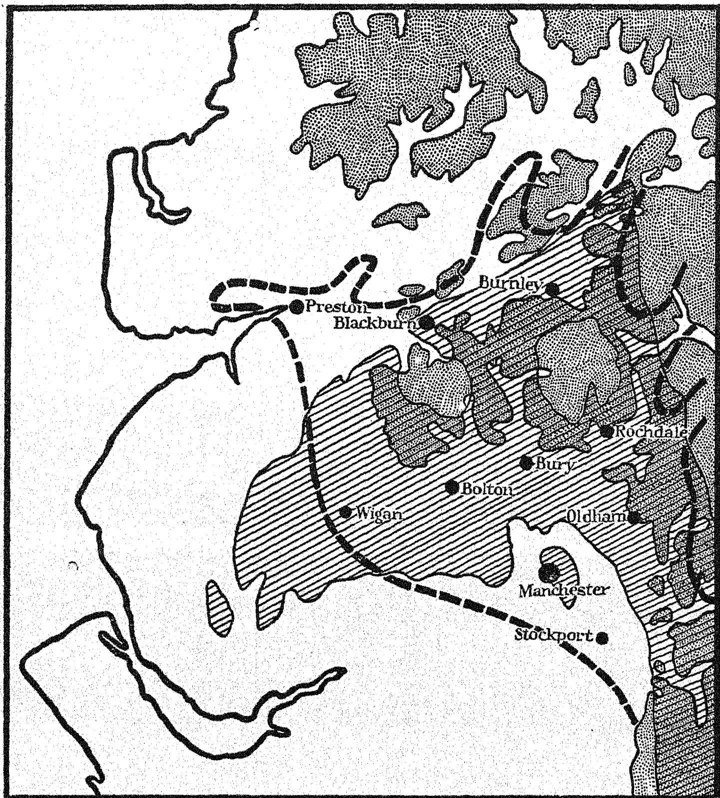


FIG. 26. DIAGRAM MAP TO SHOW THE LOCATION OF THE LANCASHIRE COTTON INDUSTRY AND ITS RELATION TO THE HILLS AND THE COALFIELD

Land above 600 feet is dotted and the coalfield is cross-shaded.

more than in spinning, though there are spinning-mills at Gargrave and at Carleton.

Within the two main regions there is much internal specialization. A textile gazetteer, giving the particular

class of yarns in which the spinning firms specialize, shows that Oldham and district mainly spins medium American yarns. The spinners of the Bolton district spin the finer

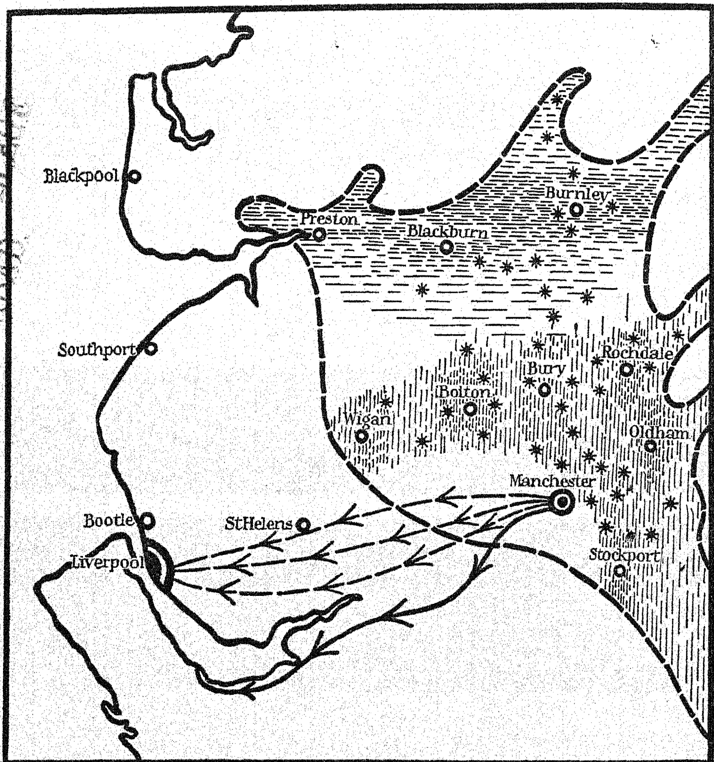


FIG. 27. DIAGRAM MAP OF THE ORGANIZATION OF THE COTTON INDUSTRY OF LANCASHIRE

No sharp separation is possible, but weaving and spinning concentrations are shown by horizontal and vertical shading respectively, and bleaching, dyeing, mercerizing, printing, etc., by the stars.

American and Egyptian yarns; over and over again one sees mention of counts of eighty and upward. The Stockport district specializes in doubling, and in the directory many firms are described as "doublers and gassers," far more than is

the case in the other spinning regions. Rochdale also engages largely in doubling, though not to the same extent. There are also many doublers in the Calder valley of the West Riding.

The weaving zone also shows much local specialization. In the small part of the West Riding which belongs to the cotton region are the weaving towns of Skipton, Barnoldswick, and Earby; here the same goods are made as at Colne and Nelson, just over the county boundary. Colne makes shirtings, checks, stripes, flannelettes, and 'fancy coloured goods' generally. Nelson makes sateens, twills, poplins, gaberdines, drills, and flannelettes. Burnley has long been famous for "Burnley printers," but the town is now increasingly turning its attention to sateens, twills, flannelettes, brocades, shirtings, and other more varied goods. Accrington makes printing cloths and light, cheap cottons for the Indian market. Blackburn and Great Harwood specialize in dhooties for the India and China trade. Preston has many Jacquard looms, in which fancy cloths are made, and it also makes sheetings, long-cloths, and flannelettes. Many of the mills in the Rossendale towns (Haslingden, Rawtenstall, Bacup) specialize in sheets, cotton blankets, plain goods and twills made of waste, as well as in other cloths made of coarse yarns.

Neither in the spinning nor in the weaving zone is the specialization complete and exclusive; but machinery suited to one class of work is not readily adapted to another, and workers who are skilled at the spinning or weaving of one class of yarn or cloth do not always turn readily to another class. It has been the fashion for some time now for writers in the London newspapers to suggest that Lancashire and the cotton industry generally need more effective organization to meet competition, and a greater adaptability toward changing fashions. These criticisms appear to be written generally by men who have no knowledge of the actual industry, and it may be fitting at this stage to quote the findings of the departmental committee appointed by the Board of Trade (to consider the position of the textile trades after the War), who reported in 1918:

> We have been much impressed by the degree of localization and of specialization in the cotton trade, and by the highly

developed systems of production and marketing, which we consider have largely contributed to the strong position of the industry.

The third great branch of the cotton industry is that which is loosely called 'finishing'—a name which is not quite adequate—but there does not seem to be any one word which would fit the circumstances. Between the various stages of the spinning and weaving, and after the weaving, there are wonderful chemical and mechanical appliances and processes which impart to the finished cloth those qualities of appearance and feel which make it saleable. There are a great variety of operations and an almost limitless variety of results. The chief operations which have a chemical basis are bleaching, mercerizing, dyeing, sizing, calico-printing, and proofing; the better-known operations which are mechanical are applied to the cloth, and may be more legitimately described as finishing. A mere list, taken from a trade directory, includes the following operations: beetling, calendering, clipping, embossing, finishing (used in the wide sense), raising, schreinering, shearing, singeing, stiffening, stretching, and suedeing.

JOHN MERCER

He studied the action of alkalis upon cotton, and this led to the discovery and later development of the process which bears his name.

The foregoing chemical and mechanical operations are carried on mainly in the central parts of the great cotton region. The main valley of the Irwell (and especially Manchester) is particularly noted for these operations. But while there is this concentration in the middle of the Manchester province, works where bleaching, mercerizing, dyeing, calico-printing, and waterproofing are carried on may be found by

the side of almost every stream from Colne and Clitheroe southward to the limit of the cotton region. These works are peculiarly dependent on a regular supply of soft water, and the moors of the Pennines, the Pendle Range, and the Rossendale Fells supply such water in abundance. The prevailing rock is grit, or coarse sandstones, and out of these sandstones, at or near their junction with shales, innumerable springs of pure, soft water issue. The rainfall on these moorlands, though not particularly heavy, is fairly evenly distributed throughout the year, and the streams seldom or never fail. This has been of great importance in the development and localization of the chemical side of the cotton industry in South and East Lancashire. This same factor applies also to the industry in general. Other factors are the moist atmosphere and the comparatively even temperature; the summers are neither as warm nor as dry as in South-eastern England, for example, nor are the winters too cold for the operations to continue throughout the year. The presence of a rich coalfield, together with plenty of good building-stone and shale, for brick-making, must not be overlooked.

In attempting to explain the localization of the cotton industry in East Lancashire and on the Pennine slopes there is a tendency to exaggerate the purely physical factors. It is clearly not enough to say that Lancashire owes its textile industry to its damp climate and its coalfield, though both are important. The average rainfall per year of Manchester for thirty-five years is 31·68 inches at Whitworth Park and 34·26 inches at Oldham Road; that of Cardiff is 41·41 inches. Clifton (Bristol) has a heavier rainfall than that of Manchester, and there is a coalfield near at hand. It is quite obvious that other factors must have played their part.

It has been explained already that Lancashire took more kindly to the new fibre than did the other textile regions; there were fewer strong guilds to resent the introduction of cotton. Also the weavers from the Continent were encouraged and given facilities and privileges. Lancashire furnished most of the great inventors in the textile industry in the eighteenth century, and Lancashire was also early in the

field in providing improved means of communication by road, canal, and railway. In later days the Manchester Ship Canal helped to consolidate further the strong position of the industry. The enterprise of the Liverpool merchants and shippers must also be taken into account. At the close of the eighteenth century, after Eli Whitney had invented his cotton-gin in America, there was a potential opportunity for a great trade; Liverpool rose to it magnificently.

To these human factors the author would add the great determination and the thrifty habits of the Pennine people; the opportunity for doing things and for making wealth in the early days attracted many strong men from the remoter Pennines who soon made their mark in the rapidly developing Manchester province. These invasions were reinforced, to the good of Lancashire, by many strong men from the Cumberland hills, from Scotland, from Yorkshire, the Isle of Man, and North Wales. The human factors have been at least as important as those of physical environment and location.

The raw cotton starts out on its career through the cotton processes from the docks at Liverpool, and to a less degree from the docks at Manchester. When it has passed through all the wonderful processes it almost invariably goes to Manchester, the great centre of warehousing, packing, and distribution for the home markets and for abroad. Manchester is also the centre for the organization, the finance, and the insurance side of the great industry. Manchester is, in fact, the pulsating heart of this, the greatest of all British manufacturing industries. The general reader may be reminded that there are far more spindles in Oldham than in Manchester, and that both Burnley and Blackburn far surpass it in the numbers of their looms.

Liverpool is the greatest raw-cotton market in the world; and Manchester is the greatest market for finished goods. The Manchester Royal Exchange is the place where most business is done. Spinners and weaving masters (manufacturers), yarn agents, cloth agents, merchants, bleachers, dyers, printers, and finishers attend Manchester to do business. Great numbers go every day, but Tuesdays and Fridays are the special market days. On these days 12,000 men

attend Manchester to buy or sell something which has to do with the cotton industry.

In the above description the cotton industry has been treated as a Lancashire industry, but this is only partly true; there are two departures from such a limitation—the cotton trade overflows into Cheshire, Derbyshire, and the West Riding of Yorkshire, and there are distinct important outliers much farther afield. On the other hand, there are parts of Lancashire where the cotton industry seems almost as remote as it does to a man of Kent or of Devon.

Lancashire may be divided into four distinct regions: the Furness division, north of Morecambe Bay, the Fylde region, between the Bowland Fells and the Irish Sea and north of the Ribble, the West Lancashire region, between the Ribble and the Mersey and west of a line drawn from Preston to Warrington, and the East Lancashire region. The cotton industry is localized in the latter region, together with a small part of Lancashire across the Ribble, including Preston, Kirkham, and Longridge. The industry clings to the hills and the coal; it seldom gets very far from these two factors.

The cotton industry overflows into Cheshire at Stockport, Hyde, Dukinfield, and Stalybridge, all of which are quite close to the Lancashire border. In the same region is a lobe of Yorkshire, including the old town of Saddleworth and a number of adjoining villages. Derbyshire is contiguous on the southern side of the Cheshire lobe here. In this region some feeders of the Mersey, the chief of which are the Tame and the Etherow, have cut their valleys back into the Pennines. In the basins of these rivers and their tributaries are the non-county boroughs of Ashton and Mossley, in Lancashire, Hyde, Dukinfield, and Stalybridge, in Cheshire, and Glossop, in Derbyshire; these towns are all engaged in similar branches of the cotton industry and associated industries.

Farther south the cotton industry sends out, as it were, feelers to Macclesfield and Congleton, in Cheshire, Leek, in Staffordshire, and Marple, New Mills, and Hayfield, in Derbyshire, with here and there an occasional factory even farther afield.

The industry can be seen to have penetrated the Pennines, or maintained its connexions through those moorlands, along three distinct lines. The important London, Midland, and Scottish line from Manchester and Stockport to Huddersfield and Leeds penetrates the Pennines by means of the three tunnels between Diggle on the west (in Yorkshire, curiously enough) and Marsden on the east. These tunnels are 3 miles 60 yards in length. One tunnel contains a double track, and is chiefly used for the slow traffic; two tunnels have each one track for fast-train traffic. Quite close to the tunnels of the railway from Diggle to Marsden is that of the Huddersfield Canal, which is no longer much used for commercial traffic, but which must have exercised a great influence on cross-Pennine traffic in the earlier days of the cotton industry. The place of the canal is now largely taken by the great main road, which is founded on that made by blind John Metcalf one and a half centuries ago. Although this road rises to a height of 1270 feet one may see big motor-wagons carrying cotton in various stages of manufacture between Huddersfield and the Colne valley on the one side, and Oldham or Manchester on the other. Huddersfield and the other towns and villages of the Colne valley district are definitely in the West Riding wool region, but there are many cotton-spinning mills and bleaching and dyeing works in that region.

Another line of connexion between the main cotton region and its outliers in the valley of the Yorkshire Calder is that taken by the Rochdale Canal, which crosses the Pennines without serious tunnelling at a height of almost exactly 600 feet above sea-level. Of course, this rise means the existence of a great number of locks, and these suggest slow transport. This independent canal is still used for traffic, but not nearly to the same extent as formerly. Almost side by side with the canal, from slightly north of Rochdale to Sowerby Bridge, is the old main line of the Lancashire and Yorkshire Railway, now part of the London, Midland, and Scottish system; this important railway line crosses the Pennines by the Summit Tunnel (or Littleborough Tunnel), which is 1 mile 1125 yards long. Keeping close company with the canal and the railway

is one of the great main roads through the Pennines, and this now takes much of the traffic which was formerly carried by the railway, and still more of that carried by the canal. The result of these means of communication is that there is maintained an important branch of the cotton industry in the Halifax district and in the upper valley of the Yorkshire Calder. Cotton-spinning and doubling, a smaller amount of cotton-weaving, and a considerable amount of dyeing and finishing represent the share of the cotton industry claimed by this Yorkshire outlier.

A third line of communication through which the cotton industry passes into Yorkshire is from the Nelson-Colne district, following the Leeds and Liverpool Canal *via* Skipton into the Aire valley. There is a secondary railway connexion through the same gap (the Craven Gap), which carries the canal, and good roads also follow the same route. A more important road, however, for modern industrial traffic cuts off a big northern bend by passing directly across the low Pennine moors from Colne to Crosshills. This road carries a great deal of heavy textile traffic between the Bradford district and the North-east Lancashire cotton region. The district from Colne to Skipton is practically given over to cotton; the valley of the Aire from Skipton *via* Crosshills to Silsden and Keighley is divided in its allegiance. East of Keighley worsted reigns, but there is an occasional cotton-mill even at Bradford. It may be noted here that many cotton manufacturers from the Nelson and Colne district are almost as diligent in their attendance at the Bradford market on Mondays and Thursdays as they are in their attendance at Manchester on Tuesdays and Fridays. A cotton-mill has recently been started at Doncaster, where there is abundant female labour available, owing to the increase of population consequent upon the rapid development of the coal-mining industry.

From almost the earliest days of the modern cotton industry the district round and including Glasgow has been interested and active in the various branches. David Livingstone was a cotton-spinner at Blantyre, near Glasgow; and the New Lanark Mills, owned by Robert Owen, have made

that region famous. All the phases of the cotton industry, as it exists in the Lancashire region, are carried on there, and Glasgow is the Manchester of that miniature cotton province. There are spinners, doublers, manufacturers, bleachers, dyers, and printers, just as in the greater province, a hundred and fifty miles farther south. The weaving masters make mixed goods to a considerable extent, and many of them are styled "cotton and woollen manufacturers."

At Paisley, in the Glasgow province, are big mills for the manufacture of sewing cotton; these mills supply a good deal of the world with the fine, strong thread used for hand-sewing and by the sewing-machine.

There are other mills for the manufacture of sewing cotton at Manchester, Bolton and district, Stockport and district, Rochdale, Great Harwood, near Blackburn, Royton, near Oldham, Skipton and the Halifax district, in the West Riding, Derby, Belper and Matlock, Nottingham and Mansfield, Leicester, Belfast, and in other parts of Renfrewshire in addition to the big mills at Paisley.

There is a considerable cotton industry at Carlisle, three firms being listed in a recent issue of Worrall's Directory. Finally there is some cotton-spinning in Northern Ireland, chiefly in Belfast, where the industry is connected with the linen manufacture.

The cotton and mixed-fibre industry of the North Midland province is dealt with in Chapter XXV.

CHAPTER XXII

THE POSITION OF THE COTTON INDUSTRY IN THE NATIONAL ECONOMY

The very important position occupied by the cotton industry was emphasized at the beginning of Chapter XX; that phase of the study must now be further developed.

The total domestic exports of Great Britain and Northern Ireland in 1937 amounted in value to £521,594,000; of this total cotton yarns and manufactures amounted to over £68,500,000, or 13 per cent. of the whole. The nearest rival of the cotton industry in this respect is the export of machinery, which was valued at £49,776,000, or 9·5 per cent. of the whole. There is also an item, "other textile materials, £20,327,000," in the usual table of values of exports. Cotton in the form of doubled yarn, and mixed in various ways with other fibres, is present in this group of exports to a degree not easily determinable. Another export item is apparel, nearly £12,500,000; it is scarcely necessary to say that cotton is represented in this group to the value of several million pounds sterling. The very important position of manufactured cotton is thus evident; and its immense purchasing power for foods, luxuries, and raw materials is quite apparent. Such an important industry should be stimulated and encouraged, and especially should its international position be kept carefully in mind.

The figures quoted above fall short, by many millions of pounds, of the statistics cited in the first edition of this book, and it is necessary next to examine rather carefully the causes of the decline in so vital an industry. In 1929 it was hoped that the depression would prove no more than temporary; since then has intervened the economic crisis (1931–32), by which no textile industry in the world was more adversely affected than that of Great Britain. It is

now obvious that nothing short of a very radical reorganization, such as that which has taken place in the iron and steel industry, will recapture for Britain her world pre-eminence in the textile market.

The seriousness of the decline is best brought out by a comparison of the value of cotton piece goods exported in a series of years chosen at random. Thus may be avoided the patent fallacy involved in comparing quantities of yarn or piece goods which may differ widely in fineness and hence in value.

Year	1924	1928	1932	1935
Value of piece goods exported (in millions of pounds sterling)	153	107	43½	39½

The depression has been most serious in the American section of the spinning branch, although it has affected all departments of the industry, except, perhaps, where certain specialities are being produced. It is well to remember that as a result of the boom in 1919–20, a great many mills which were engaged in the spinning of American cotton increased their share capital by distributing bonus shares, and many companies also increased their loan capital. Unfortunately for the trade as a whole many outside company promoters came in, bought up mills at high prices, and then floated them upon an investing public as new companies with vastly increased capital. Most of the mills which were handled by these 'financiers' had an altogether fictitious value put upon them. All this had a very serious effect on the industry.

It must be stated that the fictitious revaluation of mills was not indulged in by all the trade. The fine-spinning section was not as badly hit as the American section; and the great weaving branch did not suffer nearly so much. There was not the same temptation toward rash speculation, because far more of the weaving-mills are owned by purely private companies or by individuals. There was not the same amount of fictitious revaluation of the mills and machinery. Many of the old-established weaving firms very wisely refused to alter their nominal capital in the boom time. Still, the weaving branch has been anything but flourishing; the makers of the plainer and cheaper cotton

goods have suffered most; but the makers of fancy goods and fine fabrics have, in some cases, not done so badly. An increased use of artificial-silk yarns in association with cotton yarns has enabled some firms to produce new and attractive fabrics, and many of them have done fairly well. It must be remembered, too, that the coal dispute of 1926 hit the cotton industry very hard, as it did other industries; and the ill-effects were by no means confined to 1926.

There have been other factors at work tending to produce the serious depression in the cotton industry. Foreign competition is undoubtedly one of the factors responsible for the serious decline, although the extent of the responsibility may have been somewhat exaggerated. In 1931 differential labour and general costs enabled Japan to produce about one-fifth more cheaply than Lancashire, and it is not unreasonable to suppose that, since that day, the Japanese advantage has if anything increased. In Oriental countries two or three shifts are worked, as against one in Great Britain. Since the crisis the very excellence of British cloth has militated against it in the eyes of customers sensible of their decreased purchasing power. Problems relating to the technique and internal organization of the industry involve the whole question of the disposal of an excess of outmoded machinery in which the capital of the past forty years has been invested. Over-capacity affects the receipts of any industry, and in 1936 a step in the right direction was made by the Government in authorizing an advance of two million pounds toward the buying out of the ten million spindles at that time idle. One-quarter of the looms are also regarded as redundant. Finishing charges, which undoubtedly seem to have been too high, are another expense contributory to the decline; also rates, insurance costs, and all other incidental charges (including trade-union contributions) have been high; side by side with these overloading charges it is suggested by some that the remuneration of directors and others has been on an over-generous scale. No one particular cause is at the root of all the decline; and it is equally safe to say that there must be some sacrifice everywhere—the more drastic on account of the disdainful

neglect of such changes which has characterized the past—if the modernization, amalgamation, and standardization which alone can enable this great and famous industry to recover are to be effected.

The cotton industry of Britain used very largely to be an export trade. Seventy per cent. of the yarn spun, either as yarn or in the shape of finished goods, and 86–87 per cent. of the piece goods produced used to find their way abroad. Since the closure of many foreign markets by tariff barriers, however, a great effort has been made to monopolize the home consumer. Only about 60 per cent. of the cloth and fabric is now exported, and of this, in 1935, 50 per cent. went to the Empire. The total exports have been cut in the course of the last twelve years by more than two-thirds, the decline being most noticeable *before* the crisis of 1929.

The actual amount of piece goods sold in the home market has gone down since 1912–13, and it is important that one should think about the causes of the decline, as there has been much talk about the probability of the home market compensating to some extent for the loss of markets abroad. The causes of the lessened demand at home have probably been the high prices, which have caused people to cut down their requirements, the diminished use of linings in both men's and women's clothing, the change of fashion in respect of women's dresses, and the tendency of great numbers of people to spend more on amusement and recreation and less upon clothing.

Some of the causes mentioned above have also operated in respect of exports, and there have been other causes, such as the disturbed state of China, the increase of their own manufacture in India, Japan, and Italy, and possibly to some extent the devaluation of sterling in 1931, followed promptly by the devaluation of the yen. Neither has the recent policy of agricultural self-sufficiency been to the advantage of the textile industries. If foreign countries are discouraged from sending us their agricultural produce they cannot be expected to find other means wherewith to pay for whatever textile goods they may require. The exports have declined very seriously in the post-War as compared

with the immediate pre-War years. The biggest customer by far was, and still is, British India, but the amount exported, as measured in square yards, has gone down by 80 per cent. since 1924. The decline in shipments to China and Japan has been even more rapid; the exports to China in 1934 were 80 per cent. below those of 1932. Almost every other foreign market has shown a serious decline; the exception is Europe (without the Balkans), where a welcome increase has taken place. The decline all round, comparing 1929 with 1935, is about 47 per cent., a most serious matter indeed.

It is of great importance not only to Lancashire, but also to the country in general, to know which classes of cotton goods show the greatest decline. There is no question about the facts at home; here the decline has been greater in the cheaper classes of goods, and in those markets where little or no decline has taken place the quality of the piece goods has gone up. It is held by many that if cotton continues at its present prices, and with the present high costs of production, there seems little chance of capturing the markets in these cheaper grades of cotton cloths.

The best buyers of British cotton exports are as follows:

(*a*) *Yarns:* Germany, the Netherlands, British India, Switzerland.

(*b*) *Piece goods:* India, Australia, Argentina, China, South Africa, the Netherlands, Germany.[1] (Canada, Central America, and Mexico formerly bought more from Britain than from the United States. This position has been reversed since the Great War.)

Britain, it must by now be obvious, does not occupy the position she did in the world's cotton textile industry. Whereas in 1914 she had 29 per cent. of the total looms of the world, in 1936 this percentage had diminished to 18, of which one-quarter were considered superfluous. She still controlled in 1936 more than one-quarter of the world's

[1] This is true for the years 1927–31. Owing to the nature of the capital invested, the list of customers for piece goods is liable to alter as time passes.

spindles, although her share had fallen from 34 per cent. before the crisis of 1929 to 27½ per cent. in 1935.

An industry as great as the one under consideration finds employment for a large number of people. In the census year 1921 the number returned as employed was 620,000, made up of 234,000 males and 386,000 females—that is, 37·7 per cent. males to 62·3 per cent. females. By 1934 the number employed had fallen to 347,000. There are far more women and girls than men employed in weaving. In spinning the mule-frames are mainly run by men, but there are many women engaged in the ring-spinning section of operations. Bleaching, dyeing, mercerizing, and printing are largely done by men, and men also have charge of the machinery generally throughout the industry. Some of the lighter operations in the preparatory branches are carried on by women and girls. Until recently children were freely employed, on both half time and full time, according to age. The writer began work as a 'half-timer' in a cotton-mill at the age of nine, and became a full-time worker at thirteen. Fourteen is the earliest age at which boys or girls may be employed to-day, and from the end of 1939 it will be fifteen.

The cotton industry is peculiar in that *all* the primary raw material has to come from abroad. Broadly speaking, the amount of raw cotton required each year in the pre-War period 1909–13 was 9,000,000 quintals. In the post-War period 1925–29 the requirement fell to an average of nearly 7,000,000. And the average for the following seven years, 1929–35, was less than 6,000,000. The year 1929 was a decisive turning-point because it was in this year that Britain lost to Japan her position as the world's premier importer of cotton.

Before the Great War fully three-quarters of the raw cotton used in the British cotton industry came from the United States. The quantity is now usually about two-fifths of the whole. Egypt is the next important contributor, and over a thousand quintals of high-class raw cotton come annually from that country. Other sources are British India, Brazil, Peru, the West Indies, Nigeria, the Anglo-Egyptian Sudan, Uganda, Kenya, Tanganyika, Nyasaland, Southern

Rhodesia, the Union of South Africa, Queensland, the Fiji Islands, and Ceylon. The decrease has been effected mainly in the department of the best cotton counts, and the Empire —and noticeably India—has increased its contribution in proportion to the decreased imports from the United States. Even if India and Egypt are excluded Britain meets about one-sixth of her demand from within the Empire.

It may be pointed out that up to about 1790 the West Indies region was an important source of the raw cotton imported into Britain, but after the invention of the ginning-machine in 1793 the United States went rapidly ahead.

The British Cotton Growing Association was formed in 1902, its object being to encourage the cultivation of cotton in the tropical and equatorial parts of the British Empire. The Association has been supported by employers, employees, merchants, and persons interested primarily in the development of the Empire and its resources.

The British Cotton Growing Corporation was formed in 1921, and started with a considerable endowment, and with the promise of regular financial support from the industry. As a result of the work of the two bodies mentioned there has been considerable development in Empire cotton-growing, though not as much as was expected by some optimists at the outset. Nigeria, Uganda, Tanganyika, and the Anglo-Egyptian Sudan have made most progress.

CHAPTER XXIII

THE SILK AND ARTIFICIAL SILK INDUSTRIES

Silk

The silk industry in Britain is older than the cotton industry, but not as old as that of wool. Some attempts were made at silk-weaving in the fifteenth century, but it was mainly after the immigration into Britain of Flemish and Huguenot silk-weavers in 1585 and the immediately succeeding years, and after the Revocation of the Edict of Nantes, in 1685, that the industry took firm hold in this country. The most important early colony of silk-weavers was at Spitalfields, in London; and there were other smaller colonies of silk-weavers in various parts of England. In 1715–18 Lombe of Derby set up the first English silk-throwing mill, on the banks of the Derwent.

The silk manufacture never reached very large dimensions in the British Isles, though it was comparatively prosperous until about 1860. Since then it has declined considerably. It seems to be on the up-grade again at the present time. The volume of the industry may be judged from a study of the figures for export and import in 1937. The value of the raw silk imported was slightly over £2,200,000 sterling; the imports of silk either wholly or partly manufactured was over £2,600,000, while the value of the manufactured silk exported was under £1,500,000—that is, the exports of manufactured silk are very small compared with those of cotton or wool.

No raw silk is produced in the British Isles; the imports of unmanufactured silk come to Britain chiefly from China, France, Japan, and Italy, in the order named, but there is a considerable variation from time to time, and the disturbances in China in the past few years have upset normal conditions. The silk filaments, as they are obtained from the cocoons and reeled, are of great length, but are too fine

and delicate for weaving or knitting; they are taken in hand by the 'throwster,' who puts the necessary twist into the compounded filaments and makes silk yarn ready for the weaver or knitter. In the preparation of thrown silk there is rejected a proportion of short fibre 'waste,' and this goes with the short fibres or floss with which the cocoon of the silkworm is surrounded. This short-fibre silk corresponds somewhat to the noils of the worsted trade, and is called 'silk waste,' which is spun much in the same way as cotton or worsted. Hence there are two distinct kinds of silk yarn, thrown silk and spun silk. The chief reason for mentioning these distinctions is to point out that British mills can make excellent thrown silk, and also spun silk of a very high quality. Some authorities claim that English spun-silk yarns are the best in the world.

The chief silk goods that are produced in Britain are tie-silks, mufflers, handkerchiefs, mourning crape, and *crêpe de Chine*, dress silks, hosiery, lace, net, braids, ribbons, hat-bands, furniture silks, upholstery silks, and umbrella silks. The best customers abroad for British manufactured silks are the United States of America, Canada, Australia, British India, and the Argentine.

The industry is widespread in Britain. The chief centres are Macclesfield and Congleton, in Cheshire, and Leek and Cheadle, in Staffordshire. These towns may be regarded as in one group. Other regions are Coventry, with Nuneaton, in Warwickshire, Derby and Matlock, in Derbyshire, Bradford and Brighouse, in the West Riding of Yorkshire, with many other mills scattered through that great county; and the Manchester and Stockport districts, including occasional mills in many other towns within a radius of about a dozen miles.

More widely scattered mills are at Ripley, in Yorkshire (in the valley of the Nidd), Low Bentham, and Galgate, to the north of the Bowland Fells; Norwich, Sudbury, and Braintree, in East Anglia, and Frome, Shepton Mallet, Exeter, Cullompton, and Barnstaple, in the West Country.

There are a few silk factories in Lanarkshire, in Scotland, and one each at Ayr and Perth. In Dublin there were three silk-mills in 1924.

Artificial Silk

The attempt to make a substitute for silk is certainly many centuries old. Many a curious naturalist must have wondered what was the exact nature of the process by means of which a silkworm or caterpillar converted the tissues of leaves into the silk fibre, and must have speculated if it were not possible to imitate that process artificially. There are hints from the seventeenth and the eighteenth centuries that men were wondering if this could be done; but the first serious attempt seems to have been that of Louis Schwabe, a silk manufacturer of Portland Street, Manchester. He showed his machine for that purpose to the British Association in 1842, but that body does not seem to have been much interested.

After Schwabe's death, in 1844, E. J. Hughes of Manchester continued the investigations and made some progress; but many more years were to elapse before even a moderate measure of success was achieved. Joseph Wilson Swan, a Sunderland man, was the inventor of the carbon incandescent lamp, which brought him both fame and financial reward. He turned his attention later to artificial textile fibres, and in 1883 at Bromley, in Kent, to which town he had removed in that year, he made the first successful fibre. He exhibited his invention at the Inventions Exhibition of 1885, and used the now familiar name 'artificial silk' for the fibres.

Meanwhile Hilaire de Chardonnet in France had commenced his famous experiments in 1878, and he patented a method in 1884 which was an improvement on that of Swan's. Chardonnet's silk is often regarded as the pioneer successful fibre of the modern artificial-silk industry. Factories were started for the manufacture of the new fibre (there were three at work by 1890), and the new industry had clearly secured a footing.

Messrs Cross and Bevan were meanwhile carrying on those historic researches on the action of alkalis on cellulose which they had begun in 1880; and in 1892 they secured their patent for viscose silk, which is to-day by far the commonest of the 'artificial' silks in use. Viscose yarn and fabrics "of a very modest order" were shown at the Paris Exhibition

of 1900; and from that date to this the story has been one of intensive study and research. The post-War years have seen enormous expansion, and also continuous improvement in the production of artificial-silk yarn, in the weaving of it, and in dyeing, printing, and finishing the woven fabric. The whole industry is still very young, and it is quite impossible to forecast the dimensions that it may reach in ten or twenty years' time.

The raw materials are wood-pulp (made from spruce and pine), cotton, and flax; probably more than 80 per cent. of the world's artificial silk is now made from wood-pulp. There has been some alarm lest the demands of the new industry should draw so largely upon wood-pulp that the world's timber resources would be in danger of rapid depletion; these alarms are groundless. At least 10,000,000 tons of chemical wood-pulp are now produced per year; about 160,000 tons of sulphite pulp are at present needed for the manufacture of artificial silk.

There are four chief processes for the production of artificial silk, and four corresponding kinds of fibre. The names of these are given here, but the methods of manufacture are matters for the technical chemist. (*a*) The nitro-cellulose process is the one founded on the work of Swan and Chardonnet; this is the earliest of the processes, and the fibre made by it is accounted especially suitable for fine yarns. (*b*) The cuprammonium process is so called because the fibres are produced by first dissolving the prepared cellulose in an ammoniacal solution of copper oxide. The artificial silk produced by this method is claimed to resemble natural silk more closely than that made by other methods. (*c*) The viscose method, so called because the artificial silk is made from a viscous preparation of cellulose. This is the most important method employed to-day, and more than three-quarters of the world's artificial silk is made by it. This method is said to be the cheapest, and another advantage is that fibre with a very high lustre results from it. It is, of course, the Cross and Bevan method, resulting from original researches in 1880–92 brought up to date. (*d*) The acetate process, in which the cotton lint or high-grade pulp is treated with acetic anhydride

and strong acetic acid. This process has been described as the most interesting and most difficult of the processes. The well-known "Celanese" is made by this method. Yet another variety of artificial-silk fibre has been achieved by making each filament a tube instead of a solid fibre, as in the ordinary types. This fibre is called "Celta" a registered name well known in the trade.

All the above methods are carried out in Britain, but here, as abroad, the viscose method has far outdistanced the others. In 1936 it was estimated that the world's production of artificial silk by the four processes was 1,303,000,000 pounds, of which over three-quarters was viscose silk. A variety of artificial-silk filament now being produced by British makers is that known as staple fibre. This is made in short lengths similar to those of raw cotton or wool, and it is then spun in much the same way as waste silk, or Egyptian cotton, or wool. It is often blended in the spinning with these other fibres. A successful yarn is made by spinning together 75 per cent. of the artificial-silk staple fibre and 25 per cent. of silk, wool, or cotton. Fabrics made from the resulting yarn look very much like real silk.

The pure artificial-silk yarn, or the mixed yarn made by spinning together the staple fibre with one of the natural fibres, may be combined in weaving with the other yarns. Artificial silk is often used with a proportion of thrown silk, and a fabric is produced having attractive qualities of strength, lustre, and elasticity. Dress fabrics are sometimes made with alternate threads of spun silk and artificial silk in the warp and threads of natural thrown silk in the weft.

Artificial silk goes well with cotton, as they behave somewhat similarly toward dyes. Many varieties of composite yarns are made by spinning together these two types of fibre. Hosiery yarns are now made by twisting together artificial silk, cotton, and wool, and very beautiful colour effects are obtained.

Artificial silk is often allied with worsted, to which its properties are largely complementary, and some technologists think that it combines better with worsted than with any other fibre. Artificial silk is harsh or hard to the feel;

worsted is soft and springy. Worsted is 'hairy' and dull in appearance; artificial silk is smooth and has a glistening appearance. The new fibre is already being associated with fibres of wool in many ways, both by spinning the fibres together, to make a composite yarn, and, for example, by using the artificial silk as warp and good botany worsted as weft.

Mercerized cotton is also often brought into these mixtures of yarn and of fabric; and, in short, it is obvious that almost infinite variety of appearance, feel, response toward dyes, and capacity for finish may be reached by combinations of cotton, mercerized cotton, wool, worsted, thrown silk, spun silk, artificial silk (of the different types), and staple fibre, either in the yarn or in woven or knitted fabrics.

Linen has not been so extensively allied with artificial silk, but the firm of Raysheen, Ltd., operating at Ballymena, in County Antrim, claim to have made possible a highly successful union of these fabrics.

While on the subject of combining artificial silk with other fibres, it may be mentioned that Lancashire alone takes several million pounds of artificial silk, of which amount most is used in the cotton industry.

Great Britain and Northern Ireland produced over 54,000 tons of artificial silk in 1937;[1] this was more than the production of Italy and about one-third of that of the United States. The total production of the world for the same year was about 549,000 tons, so that the United Kingdom accounted for about 10 per cent. of the world's output. The amount produced by the United Kingdom in 1930 was a little over 21,000 tons, so that in seven years the amount has been considerably more than doubled.

There is considerable misconception with regard to the part played by artificial silk in the textile industries of the British Isles. It has made amazing progress in a very few years, but it has far to go before it can compare with cotton; the amount by weight of artificial silk produced in 1928 was not more than a thirtieth of the raw cotton imported. This comparison is given not with a view to belittling the

[1] Including artificial straw.

wonderful advance of artificial silk, but in the hope that it may correct certain popular misconceptions, due in no small measure to erroneous statements in some of the newspapers.

The last question concerning this newest member of the textile family is "Where is it being located in Britain?" The answer is almost predetermined by the present location of the cotton, wool, and silk industries. The new fibre certainly finds its way mainly into East Lancashire, the West Riding of Yorkshire, Macclesfield and district, and into that great, more miscellaneous province which includes Nottingham, Leicester, and Derby. Knowledge of spinning machinery, of looms, of various kinds of finishing processes, of dyeing and printing, is a great asset. Many old-established cotton manufacturers in Lancashire and worsted manufacturers in the West Riding of Yorkshire have taken up the new fibre, chiefly, of course, in association with the fibres with which they have so long dealt. Recently artificial silk has been taken up in those cotton districts which are accustomed to what, in the cotton trade, are called 'fancies.' Silsden, Skipton, Colne, Nelson, Clitheroe, Darwen, to select almost at random, are towns where many varieties of mixed goods are being produced, with artificial silk as a constituent. The manufacturers there, as elsewhere, are recognizing the value of the latest comer in alliance with the cotton and worsted to which they are so thoroughly accustomed. The "lack of adaptability" of the manufacturers of the West Riding and of East Lancashire is a myth.

The manufacture of the primary product is to some extent determined by facility for importing spruce timber, wood-pulp, and cotton linters. The use of so many chemicals in the manufacture, such as sulphuric and nitric acids, ammonia, caustic soda, carbon bisulphide, and acetic acid, makes it an advantage to be near one of the great chemical regions. Nearness to water-supplies, accessibility of labour, the possession of mills which are not too heavily rated, and ready means of transport are other factors, together with nearness to the regions where the manufactured fibre can be used. New factories are being opened from time to time, and a correct list to-day would very soon be out of date. Some of the

localities at the present moment are Lancashire, the West Riding of Yorkshire, Derby, Nottingham, Burton-on-Trent, Coventry, Wolverhampton, Peterborough, Bristol, Greater London, East Anglia, South-west Scotland, and North-east Ireland.

The special machinery for the artificial-silk trade is made at Bolton, Manchester, Keighley, Macclesfield, Leek, Nottingham, and Leicester. Some of the old-established firms that have long dyed, printed, and finished cotton or worsted or natural silk goods have taken up the like functions for the combinations of artificial silk; most of these firms are to be found in East Lancashire and the West Riding.

It is not easy to estimate the number of persons for whom the artificial-silk industry finds employment, because all the official returns group the artificial-silk industry with the silk industry, and also, as will be evident from what has been mentioned, because there is so much combination of the new fibre with the older, more familiar ones. In 1930 silk and artificial silk manufacture engaged 60,000 people, an increase of 20,000 in six years—due no doubt to the wide use of artificial silk. No official figures are available for the quantity of artificial silk used in any of the industries—cotton, wool, silk, hosiery, or knitted goods; but there is no doubt whatever that the export of goods in which artificial silk forms part is growing rapidly. The advent of this fibre, or group of fibres, has proved a welcome stimulus to some industries which were feeling the effects of several adverse factors, and its influence has been wholly to the good. The chief unsatisfactory feature is the intrusion into the financial side of the industry of so-called outside 'financiers,' and the manipulation of the markets to the detriment of the steady working and development of the industry itself.

CHAPTER XXIV

THE TEXTILE INDUSTRIES: THE MINOR FIBRES

Flax and Linen

The spinning of flax and the manufacture of linen fabrics constitute one of the oldest of the British textile industries. Linen manufacture was a domestic industry until the beginning of the nineteenth century. Ireland was already noted for linen in the early seventeenth century, and in *The Treasure of Traffike*, by Lewes Roberts, merchant, published in 1641, one reads: "The town of Manchester buys the linen yarn of the Irish in great quantity, and weaving it, returns the same into Ireland to sell."

The industry began to make considerable progress in Ireland when Huguenot refugees from France settled there after 1685, for they introduced new methods of bleaching and of manufacture. During the latter part of the eighteenth century Irish linens of various kinds achieved a great reputation.

The flax plant, from the stem of which linen fibre is obtained, may be grown under widely different conditions of climate, in both temperate and sub-tropical regions. The flax plant is grown not only for the fibre, but also for its seed (linseed); as a rule, however, the plant is grown for *either* fibre *or* seed—one only.

The only British region where flax is grown in considerable quantities is North-eastern Ireland. The average acreage under flax is about 25,000 acres. A little flax is grown in Scotland, and a little in England and Wales (seldom more than 1000 acres are under flax which is being grown for fibre in England and Wales in any one year). The linen industry is therefore largely dependent upon imports from the Netherlands, the Baltic states, and Russia.

The flax is pulled up by the roots soon after the fruit has begun to form, and is then placed in three or four feet of water to prepare it for the extracting of the fibre. A process

of fermentation is started, and this softens and finally renders soluble the covering of the desired fibres. There are several different methods of carrying out the retting process, as it is called, but these must be studied in the technical literature of the subject.

The separated linen fibres are dried and then passed through processes somewhat analogous to those of the cotton industry—scutching, combing, hackling, and sorting, ready for spinning. The combing, as in the case of the other textiles, separates the better quality or long fibre—'line,' as it is called—from the short fibres, or 'tow'; the long fibres correspond, in a way, to the 'tops,' and the short fibres to the 'noils,' of the wool industry. Other preparatory processes similar to those in the cotton industry are called spreading, drawing, and roving; and then comes the spinning process, which makes the fibres into the solid round threads, which are called linen 'yarn.'

The yarn is now a semi-manufactured article, and much British linen yarn is exported, because there are many countries which weave linen cloth but have not the skill or the necessary machinery for making fine and even linen thread.

The linen yarn at this stage is the foundation of two industries: (i) the smaller is the making of linen sewing-thread; (ii) the larger is the weaving of various kinds of linen cloth. Very often, as in the cotton trade, there is some specialization of processes in the industry; one mill spins, another makes sewing-thread, a third weaves, and yet another bleaches and finishes the yarn or the fabrics. As in other branches of the textile industries, there are many 'union goods' made—that is, goods in which more than one kind of fibre is used—such as, for example, the warp of linen, the weft of cotton. As an example, a Northern Ireland "bleach and dye works" announces that it bleaches and finishes all classes of linen, union, and cotton goods.

The linen industry, though once a widespread home industry, is now chiefly located in certain well-defined regions in Britain. The most important of these is North-east Ireland, where over 100,000 people find employment in the industry directly or indirectly. The industry is carried on in nearly

every town and village in Northern Ireland, but by far the greater part of the output is produced within a radius of thirty miles from Belfast. At the latter city are the largest

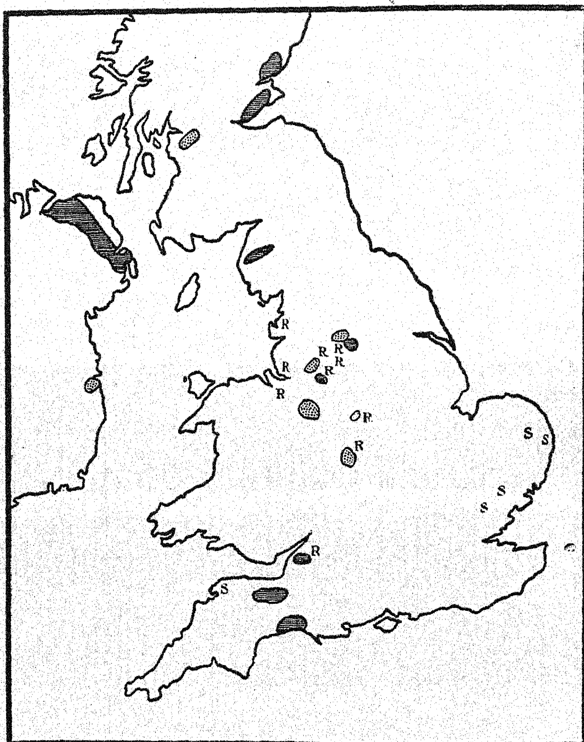


FIG. 28. DIAGRAM MAP OF THE MINOR FIBRES USED IN TEXTILES

Shaded, flax (linen), jute, hemp, ramie; dotted, silk; S, scattered silk-mills; R, rayon (artificial silk).

linen-mills in the world, the famous works of the York Road Flax Spinning Company, Ltd. This company carries on the processes of spinning flax and weaving and finishing linen goods, and they have their own bleaching works at Muckomore, about twenty miles from Belfast.

Other places where there are important flax-spinners and linen and linen-thread manufactures are Ballymena, Banbridge, Cullybackey, Doagh, Dungannon, Dunmurry, Lisburn, Lurgan, Newtownards, and Portadown. In Éire (Ireland) the industry is carried on at Dundalk, Drogheda, Balbriggan, and Dublin.

The next region in importance is Eastern Scotland. Here, in Fifeshire, are the important centres of Dunfermline, Kirkcaldy, and Cupar; in Angus (Forfarshire) are Arbroath, Brechin, Forfar, and Dundee. In the latter town the linen industry is overshadowed by the cognate jute industry, of later development. Aberdeen also has a flax mill.

The number of people employed in the Scottish linen industry is probably about two-fifths of the number employed in Ireland in the same industry.

In England and Wales the industry is more widely scattered. There are a few flax-, hemp-, and tow-spinners and linen manufacturers in Yorkshire, at Leeds and Barnsley, Bradford, Cleckheaton, Huddersfield, in the valley of the Nidd, and at Northallerton. In the Lancashire district mills exist at Manchester and Stockport; and in other parts of England there are flax-, hemp-, jute-, and tow-spinners and linen manufacturers at Cleator and Cockermouth, in Cumberland, Barnard Castle, in Durham, Marple and Ripley, in Derbyshire, Birmingham and Bromsgrove, in the Western Midlands, Wotton-under-Edge and Bristol, in Gloucestershire, Bridport, in Dorset, Fordingbridge, in Hampshire, Haverhill, in Suffolk, and at Crewkerne, Ditcheat, Ilminster, Yeovil, and Martock, in Somerset. Crewkerne, in South Somerset, and Bridport, in Dorset, are the more important of these South Country towns, where twines, nets, and sailcloth are the commoner productions of their mills.

The number of people employed in the industry in England is far smaller than in Scotland, and is very small compared with the number in Ireland.

There is an immense variety of goods produced in the British Isles, ranging from the finest and most expensive table-linen, fine, gossamer-like muslins, to heavy, coarse sailcloths.

Jute Manufacture

It should be pointed out that jute is somewhat of an ally of linen in certain of the industries mentioned above. It has, indeed, suffered from being regarded as an inferior kind of flax, for which the same machinery could be adapted, whereas in fact it requires special and individual consideration. To none of the textile industries has chemical research, such as is carried on in Manchester and Luton, been more profitable. Jute is a much cheaper fibre, and is used for the manufacture of coarse-woven fabrics, such as sacking, horse-cloths, inexpensive carpets, and also for the cheaper kinds of cordage. It is also the basis of linoleum and floor-cloth.

The jute of commerce grows only in wet, tropical regions.

To obtain the jute fibre the stems of the plant must go through a retting process somewhat similar to that applied to flax, the purpose of which is to remove the cuticle or covering of the strong bast fibres of the stem. When the retted fibre is thoroughly dried the jute is sorted into jute proper, rejections, and cuttings.

Almost all the jute of the world is produced in India, chiefly in Bengal, but a proportion comes from Nepal and Formosa. The jute used in British mills is imported mainly from Calcutta and Chittagong.

Jute seems to have been first spun and woven at Abingdon, in Berkshire, in the early nineteenth century, but the name of that town no longer appears in textile directories.

In the thirties of last century experiments to test the properties and uses of jute were carried out in Dundee. It is claimed that some of the success which attended these trials was due to the use of whale oil, a product then common and cheap at Dundee. This oil softened the fibre and made it easier to spin and then to weave. The great opportunity of Dundee in regard to jute came at the time of the Crimean War, when the supplies of Russian flax and hemp were cut off for a time. The Scottish town and district went ahead and became the greatest centre of the jute manufacture in the British Isles. In Dundee and about twenty miles round are some fifty-five firms engaged as jute-spinners and

manufacturers. There are, of course, occasional mills in other regions.

Seventy per cent. of the raw materials, foodstuffs, and fibres of the world are carried in jute covers, but bulk transport, which obviates the need for sacks, is a serious competitor.

Hemp

The true hemp is grown as a fibre-yielding plant in many European countries, especially in Italy, Hungary, Czechoslovakia, and Russia. This plant also must go through a retting process, followed by processes similar to the breaking and scutching applied to flax. As hemp is not used extensively for real textiles, owing to its lack of flexibility, it is not spun in the same way as flax. The fibres are much more rigid and coarser than those of flax, but as they are longer they lend themselves to the manufacture of ropes, twines, and cables; at the same time hemp is used, sometimes along with jute, to make nets, sailcloth, canvas, and tarpaulins. Hemp is often used for warp and one of the other strong fibres for weft, especially in the weaving of carpets.

Wool and jute form a common and desirable combination in such circumstances—that is, jute as warp and wool as weft. The flexibility and softness of the wool fibres tone down the rigidity of the hemp fibres.

The carpet industry may be mentioned here rather more fully. It is often regarded as a special branch of the wool trade, but it should be noted that almost all kinds of textile fibres may be used in the carpet manufacture—wool, cotton, hemp, and jute, and some of the 'substitutes' for the latter two are all used in various degrees and in many combinations.

After all, however, the greatest use of hemp is in the manufacture of rope and twine, and this industry is carried on very widely in Britain. Some of the biggest users of hemp fibre have their mills in those regions where flax and jute-work are manufactured—for example, the Belfast Ropework Company, in the heart of the flax-manufacturing region of North-eastern Ireland. The works of the company just mentioned are said to be the largest of their kind in the world.

A glance at the various productions of the mills at Bridport, in Dorset, as given in the directories, shows the interrelation and the interdependence of flax, jute, and hemp.

THE CARPET INDUSTRY

The carpet industry shows by its location its intimate association with wool, for two at least of its chief districts are the West Riding of Yorkshire and the wool regions of Scotland. Carpet manufacturers are found in the West Riding, at Halifax, Sowerby Bridge, Brighouse, Liversedge, Heckmondwike, and Leeds.[1] In Scotland the carpet and rug manufacturers are very widespread, and one almost despairs of making a statement of any particular locality. At the risk of accidental omission of some important mills, the following districts may be mentioned: Ayr, Kilmarnock, Paisley, Glasgow, Perth, Stirling, and Dysart (Fifeshire).

The most important English region that devotes itself more especially to the carpet industry is Kidderminster and district. In Kidderminster alone sixteen firms of carpet manufacturers were recently listed in Worrall's directory. Axminster, Brussels, and Wilton carpets, as well as velvet pile, "Persian," and other styles are made in this "metropolis of the carpet industry."

There are many other districts or individual towns in which the carpet industry finds a home. South Lancashire naturally comes to one's mind. Here there seem to be only three firms, one at Manchester, one in Rossendale, at Waterfoot, and one at Rochdale, which bears the historic name of John Bright. Other English towns are too numerous to be all given here; they range from Carlisle, in the north, to Merton, in Surrey, and Melksham, in Wiltshire. It is significant to note that neither Axminster nor Wilton appears in the lists of towns where carpets and rugs are manufactured. Wilton possesses felt-mills, where felt cloths, baizes, etc., are made, but carpets are not listed.

There do not seem to be any carpet manufacturers, in the strict sense, in Wales; but two firms, far apart, one in

[1] See also Chapter XIX

Anglesey, the other in Carmarthenshire, are makers of rugs. Carpets and rugs are sometimes made by the same firms, but much more frequently the making of rugs goes with the making of flannels, blankets, baizes, and felted woollens. This is another example of that common overlap of one industry and another which runs through the whole of the textile group.

Linoleum, Oilcloth, etc.

It was mentioned above that jute and similar fibres usually form the basis of linoleum and oilcloths; hence this branch of manufacture is often located not far away from the textile regions where fibres and their properties are well known and where textile machinery is made. There is also the dependence upon specially prepared oxidized linseed oil, in which solid gums, such as resin and kauri gum, are dissolved or mixed, often accompanied by rasped or ground cork; there are also needed dyes and other colouring matters and inorganic powders used as filling substances; these considerations influence the location of this highly specialized industry. Coming from north to south, the chief manufacturers are at Dundee, Kirkcaldy, Falkland (Fife), Newburgh (Fife), Northallerton, Sowerby Bridge (West Riding), Lancaster, and Chorley. The towns which carry out the industry on a large scale are Kirkcaldy and Lancaster.

Substitutes for Hemp and Jute

Before this chapter is closed it should be mentioned that there are now very many so-called substitutes for hemp and jute. They are all derived from the long stems or leaves of plants which have bast fibres below the cortex or cuticle, and there must be some process which is analogous to or takes the place of the retting process used in hemp. Practically all the plants are grown in sub-tropical, tropical, or equatorial regions.

Sunn hemp, perhaps better known as Bombay hemp, comes to Britain from India, and finds a ready market as a

cheaper substitute for the true hemp. It consists of the bast fibres of the stem of a leguminous plant.

Manila hemp is grown almost exclusively in the Philippine Islands; it is derived from the sheaths of the leaf-stalks of a plant of the plantain family. The fibres of this plant make strong rope and twine, and it has long been held that manila rope forms the best, if not the only, suitable material for marine cordage (but see below, under sisal).

Mauritius hemp is a member of the agave family, and is probably native to tropical America, although it is now grown in many tropical lands, including St Helena, Mauritius, Ceylon, North Australia, Natal, Nyasaland, and Northern Rhodesia. The fibres of this plant are used for rope manufacture, especially when mixed with manila hemp and sisal fibre.

New Zealand hemp, or phormium, was first noticed by Captain Cook. It is obtained from the leaves of a plant of the lily family. Its fibre is soft, lustrous, and flexible, and the finer varieties are sometimes used in place of flax, and are woven into fine textiles; the coarser fibres are used for rope and twine manufacture and for floor-matting.

Sisal 'hemp' now stands somewhat apart, because of its very wide use in the rope and twine industry and in the manufacture of very coarse sacking. Sisal (the word 'hemp' is commonly omitted nowadays) is so called from the name of the port in Northern Yucatan, Central America, from which it was first obtained. The fibre is somewhat related to Mauritius hemp in that it is obtained from the leaves of a plant of the agave family.

Sisal fibres consist of strands from three to five feet in length. The fibres are very strong, but not as soft and flexible as manila hemp or Mauritius hemp; hence the use of them mixed with other fibres is now quite common.

Sisal is, perhaps, the favourite fibre for the making of cheap binder twine, and for this purpose it is widely used in Britain. It was claimed by the Empire Marketing Board that good sisal rope may safely be used for marine purposes, as it withstands the action of sea-water quite well. British sisal now comes largely from the British Dominions in tropical

and equatorial West Africa and East Africa, as well as from the British West Indies.

Ramie, or China grass, also stands somewhat apart, because it is more difficult to prepare from the grass-like members of the nettle family from which it is obtained, and when prepared it has somewhat different properties. The cuticle or cortex of the stems cannot be removed by ordinary retting, but must be removed by chemical means, and the process known as degumming is usually carried out in England. Decorticating machines have been invented by the English textile machinists which now remove the outer covering quite successfully. The ramie-spinners often buy unprepared ramie from China or Malaysia in the form of ribbons, after it has been well hand-cleaned there; then caustic soda and afterward bleaching-powder, or one of the hypochlorite solutions and dilute acids, are used to complete the removal of the gummy matter.

Ramie fibre is very strong and lustrous, but is somewhat lacking in flexibility. It is now frequently combined with worsted for the weaving of mixed fabrics; it is also woven unmixed for the making of tablecloths and carpets, and is sometimes combined with linen or New Zealand hemp fibre for that purpose. Ramie is also used for making the fabric for incandescent gas-mantles, and one well-known type of mantle is named after the word ramie spelt backward and begun with the letter *z*—Zeimar mantles.

There are many other fibres, which are used as yet only in small quantities, either for various types of cordage or for coarse, cheap matting, or baskets and sacking.

CHAPTER XXV

THE MINOR TEXTILE INDUSTRIES: LACE, MUSLIN, EMBROIDERY, FABRIC GLOVES, AND SMALLWARE

The preceding chapters have dealt with the major textile industries, grouping them according to the particular fibres which are the bases of them. It now remains to consider a widespread group of industries which use cotton, wool, silk, artificial silk, and linen in an almost endless variety of adaptations and combinations.

John Heathcoat

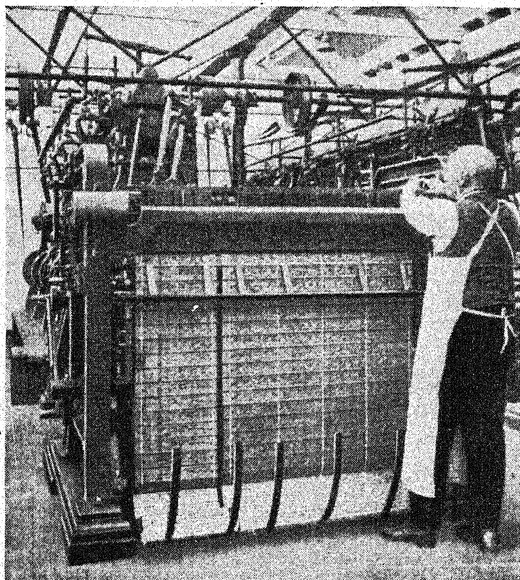
Lace

The manufacture of lace in the British Isles by machinery is of course modern, dating from about the end of the eighteenth century or the beginning of the nineteenth. William Lee, a clergyman of Nottingham, had invented a knitting-machine or knitting-frame as far back as 1589; but the lace industry remained a domestic occupation. The making of pillow lace was probably introduced into Britain by refugees from the Low Countries in the early part of the seventeenth century. Some of these refugees settled in Bedfordshire in 1626, and from this county the art spread to other parts of the country as a cottage or home industry. This lace is still made in Bedfordshire, but not as a factory industry.

There were attempts in the latter part of the eighteenth century to produce lace by machinery, and it was found that the knitting-frame could be adapted for the purpose. The well-known net mesh was made by machinery at this time,

stages in the adaptation having been made in 1768 and 1786 respectively. In 1808 and 1809 John Heathcoat, a native of Duffield, near Derby, invented the double-tier or bobbin-net machine, an invention which gave a great impetus to the lace manufacture.

John Leavers adapted the famous Jacquard system of healds to his lace-frame in 1834; this invention made it



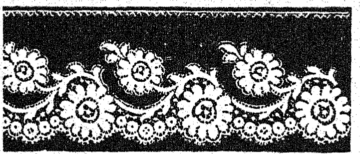
A Modern Jacquard Loom employed in the Lace Manufacture

possible to produce fancy designs and figures without having to darn them in upon the nets 'woven' by Heathcoat's machine. This invention replaced the hand-work of thousands of women who had been employed in inserting the patterns in Heathcoat's net lace.

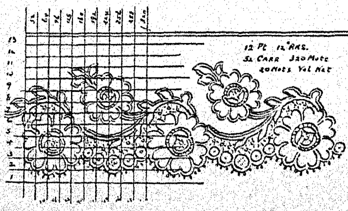
Many further improvements and more or less incidental developments have been added to the achievements of these fundamental discoveries, and these have brought machine-made lace to its present high standard of perfection.

A modern lace-making machine—an immense assemblage of mechanisms—is surely one of the greatest marvels of modern textile machinery. There are said to be 2400 of these machines in use to-day in the Nottingham lace-manufacturing province.

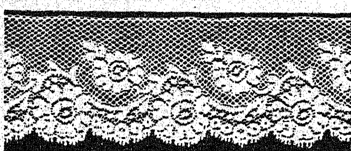
Nottingham and district was certainly the original home of the manufacture of lace in factories, but within the last thirty years Ayrshire has become a keen competitor, especially in the important branch of lace-curtain manufacture.



THE DESIGN AS DRAWN



THE DESIGN SQUARED FOR THE DRAUGHTSMAN



THE DESIGN IN LACE

THE PRODUCTION OF FIGURED DESIGNS IN LACE

Three stages are shown.

There are many large factories in Nottingham and district devoted to various branches of lace manufacture, but the organization of the industry has developed on lines which have allowed 'little men' to become manufacturers; they obtain their machines on the hire-instalment plan, pay for space and heating in a building which is let off for the purpose, and obtain electric power from the municipal or other electricity service. In consequence, there are a great number of small makers, some of them sharing the same mills, and the list of names in a business directory becomes very long; out of about 400 entries in one, 180 (or nearly one-half) have factories in the city of Nottingham or its suburbs, and 81 in Long Eaton, just within the borders of Derbyshire. No other places compare with these, but it does not follow that the total manufacturing capacity of Long Eaton is one-half of that of Nottingham. About one-fifth of the Nottingham working population is employed in textiles.

The prosperity of the lace industry is very dependent upon fashion, and the manufacturers live by their adaptability.

The Nottingham lace province stretches to Loughborough,

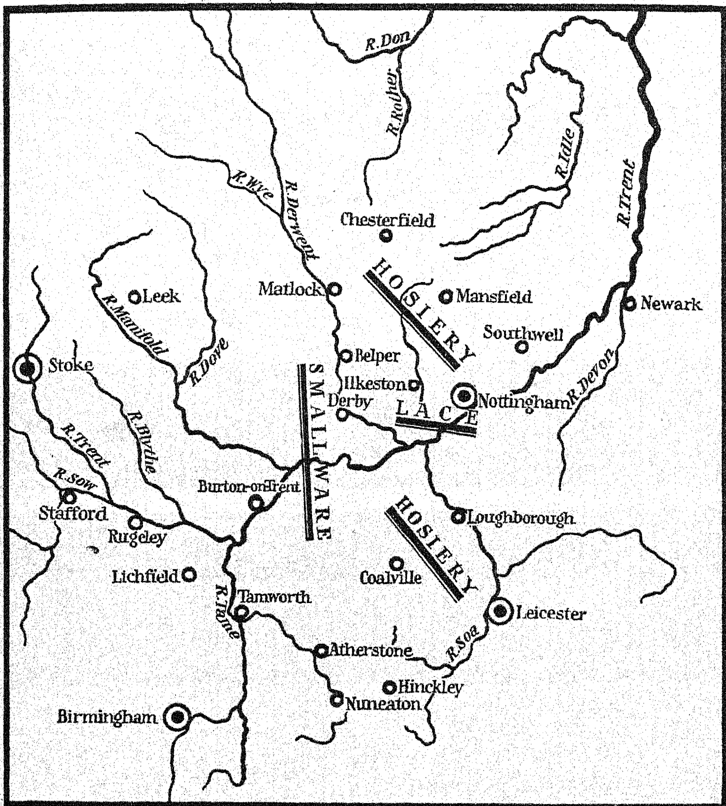


FIG. 29. SKETCH MAP OF THE MIDLAND REGION WHERE HOSIERY, LACE, AND SMALLWARE ARE MANUFACTURED

Derby, Sutton-in-Ashfield, and Southwell, and within those limits it is supreme. Farther afield in England there are lace manufacturers at Leicester, Barnstaple, and Chard (Somerset).

The other province of lace manufacture in Great Britain

is in Scotland, practically all of it in Ayrshire. The chief centres are at Darvel, a town nine miles or so east of Kilmarnock, and at the neighbouring town of Newmilns. There are also lace manufacturers at Kilmarnock and at Galston. Outside Ayrshire there is a very small part of the industry at Glasgow. The mills are described as for the manufacture of lace and muslins. Several firms have branches both in Ayrshire and Nottinghamshire, with London and Manchester addresses for sales purposes.

Muslin Manufacture

This industry is now practically confined to the West of Scotland, and is located in Ayrshire and Lanarkshire. In Ireland there are manufacturers of muslins at Belfast; and in England at Carlisle.

Embroidery

This is the art of working designs upon a woven fabric, sometimes upon a plain net. Nottingham has some hundreds of machines which are engaged in embroidery work. Many of the larger linen-mills do embroidery work on their own fine linen as a basis. In connexion with the linen manufactures of Belfast and district there is a considerable home industry in hand-embroidery of handkerchiefs, table-centres, etc.; this work is carried on mostly in County Down and County Donegal. The large linen-weaving mills in York Street already mentioned have some wonderful machines for working patterns of many kinds, from the simple letters of the alphabet to the finest and largest embroidered bedspreads and tablecloths. The machines are worked individually, the movements of the needles and the frames being controlled and directed by hand; doilies, table-centres, afternoon tea-cloths, pillow-cases, bedspreads, etc., are embroidered with most beautiful floral and other designs.

Fabric Gloves

This industry uses as its raw material wool, worsted, Egyptian cotton, silk, and artificial-silk yarns; and it is

naturally located where the hosiery manufacture is also carried on. The machinery is analogous, the processes are similar, and the fibres used are broadly the same; in fact, it is often regarded as a branch of the hosiery industry.

At the beginning of the Great War almost the whole of the British markets in fabric gloves had been captured by German manufacturers. This was, of course, lost to the Germans during the War, and since then the British manufacturers have made determined efforts to retain a large share of the trade.

The chief region for the manufacture is the county of Leicestershire, including Leicester itself and almost all parts of the county. The industry oversteps the county boundary and is found also at Melbourne and Derby, in South Derbyshire, and in Nottinghamshire, at Sutton-in-Ashfield and the county town. Frome, in Somerset, and Bideford and Barnstaple, in Devon, are other towns where fabric gloves are made.

In Scotland the industry is not so closely localized, the chief towns being Dumfries, in the south, Aberdeenshire in the north-east, and Edinburgh.

Ireland has one factory at Glenties, in County Donegal.

The Smallware Textile Industry

This is a somewhat diffused industry, which concerns itself with the manufacture, mainly by weaving, of narrow fabrics for special uses, from a boot-lace to an elastic-web kneecap or belt. There is a great variety of products for personal use, use in the upholstery trade, in the home, in the hospital, and in some of the other trades. A full list would be long and wearisome, but an abbreviated one may be useful—tapes, tassels, cords, gimps, boot- and shoe-laces, corset-laces, elastic webs, surgical bindings, surgical dressings, elastics for garters, suspenders, braces, fringes for curtains, rugs, braids of many kinds, school and club badges, woven labels, medal ribbons, boot-tabs, coat- and dress-hangers, etc. The list, although quite incomplete, shows the usefulness and the far-reaching character of the industry. One firm in the West Riding of

Yorkshire sums up the scope of the industry, in a way, by announcing that they weave all kinds of fabrics from a quarter of an inch to six inches in width. There is much more than plain weaving involved, however, as appears on very slight consideration; many of the fabrics are gimped or knotted or looped in some way; there are very many kinds of metal fittings; and by mixing many kinds of fibres there is much variety introduced, including covered rubber bands, often of a remarkable degree of fineness.

This industry, in some of its branches at least, is obviously related to home industries, for many of the things enumerated are still made in the home. It is, perhaps, a natural consequence that much of the factory industry in these goods is done on a small scale, by people with no great capital invested, and whose output is not very large. Some of the machines, however, are elaborate and expensive. There was, for example, a new and wonderful type of tape-weaving loom exhibited by Thomas French and Sons of Manchester at a recent British Industries Fair which made a double tape with draw-cords woven in ready for pleating. Such a machine must of necessity be somewhat costly to make.

This smallware industry shows a definite distribution and specialization. Three towns stand out as centres, but in each case the industry is overshadowed by other and greater ones. Manchester has always been noted for such goods, and at one time they were actually known as 'Manchester wares.' There are now about a score of factories in Manchester itself, and the industry extends northward, with a single factory here and there, to Middleton, Heywood, Bury, Radcliffe, and Farnworth, all within ten miles of the centre of Manchester, which is still a great market for the finished goods.

Derby is also a distinctive centre of the smallware industry, and specializes in some of the very narrowest of the goods included in this wide group. The industry extends outward from Derby in all directions, in scattered small factories here and there. Ashbourne, Wirksworth, Matlock, and Ripley, and even more distant Chesterfield, to the north of Derby, and Borrowash, to the south-east, are partly engaged in this branch of fabrics. The smallware industry may be said to

overflow into Staffordshire, where factories are found at Burton-on-Trent (which is situated athwart the county boundary between Derbyshire and Staffordshire), at Cheadle, Leek, and Tean, near Stoke-upon-Trent. On the Leicestershire side the smallware industry is carried on at Coalville, Whitwick, Quorn, and Loughborough, at Leicester itself, and at Wigston, south of the county town. In Nottinghamshire it is found at Nottingham and at Hucknall Torkard, a few miles farther north.

The third focus of the smallware industry is at Coventry, in Warwickshire. Here, as might be expected from that city's long association with the silk industry, the smallwares have a distinct silk and artificial-silk connexion, and may be regarded as naturally allied to the ribbon manufactures of that famous city; in fact, some of the firms are listed in Worrall's Directory under both ribbon manufacturers and smallware manufacturers. Other places within a short distance of Coventry where the smallware industry is carried on are Birmingham, Kenilworth, Nuneaton, and Bulkington and Bedworth, both near Nuneaton.

Outside these major regions the smallware manufacture is located at Macclesfield and in the West Riding of Yorkshire, where there are half a dozen factories scattered over the region. There are isolated mills at Edgware, in Middlesex, Martock, in Somerset, Wotton-under-Edge, in Gloucestershire, Boston, in Lincolnshire, and Johnstone, in Renfrewshire.

The industries considered in this chapter cater largely for the home trade, in which there is a considerable demand for the wide variety of goods produced. There are also some exports, and that in lace is by no means negligible. The exports are not, of course, for any of the branches, comparable with the exports of the two chief textiles, cotton goods and woollen goods. A large proportion of the goods manufactured will obviously be retailed as part of some kind of clothing, and a considerable share of the value of exports of apparel must be credited to the many kinds of 'smallware'—braid, trimmings, etc.—which form part of the apparel.

The exports of textile yarns, textile fabrics, and apparel

may be given in summary form to show the important share claimed by the British textile industries as a whole in the export trade of Britain.

EXPORTS FOR 1937 IN VALUE

Cotton yarn and cotton manufactured goods	£68,532,000
Woollen and worsted yarns and manufactures thereof	£35,486,000
Silk yarn and silk manufactures . .	£1,491,000
Other textile manufactures: linen, jute, mixed, smallwares, etc. . . .	£20,327,000
Clothing of all kinds	£12,399,000
Total of textiles and clothing . .	£138,235,000
Total domestic exports . . .	£521,594,000

That is, textiles and clothing furnish almost exactly one-third of the whole of the domestic exports of Great Britain and Northern Ireland.

SECTION D

SOME DEPENDENT AND LESSER INDUSTRIES

CHAPTER XXVI

THE CLOTHING MANUFACTURE

IN the preceding chapters the manufacture of textile fabrics has been studied. The main theme was the manufacture of the fabrics themselves—that is, the production of cloth made of cotton, wool, worsted, linen, silk, artificial silk or rayon, or of two or more fibres mixed together. To the textile manufacturer these are finished goods; to the clothing manufacturer they are raw materials; hence the study of the last-named industry comes naturally at this point. It is obvious that there is a zone of overlap between the textile manufacture and the clothing manufacture. This is illustrated in many ways and in many districts. A Leicester hosiery manufacturer may begin with the desired yarn and turn out the finished hose from his factory. A Hebden Bridge fustian manufacturer may begin with the yarn, weave the fustian cloth, carry out the ribbing and the pile-raising processes, and then may make the fustian clothing. An East Lancashire flannelette manufacturer may make men's shirts, though he is likely to have his shirt factory in or near Manchester, while his weaving factory is at Preston or Burnley.

The above are illustrations of the general principles of overlap; but, on the whole, there is a distinct separation of the two great groups, the weaving of fabrics and the making of clothes. This chapter is headed "The Clothing Manufacture." Logically under this heading should be included the knitting of stockings by the fireside and the making of underclothing in the home. There are still thousands of

people who seldom buy factory-made articles of the above descriptions. The work of the village tailor and dressmaker and shoemaker would also strictly fall within the theme of this chapter. Actually the study will concern itself with the production of these things in those factories which are given up to that work only, where mechanical power is applied, a number of people are employed, and the particular goods are sold wholesale to the shopkeeper or the exporter.

The clothing manufacture as defined above is a very considerable industry. It finds employment for 500,000 people, satisfies the demands of about three-fifths of the home market, and provides exports to the value of £13,000,000 in a fairly normal year.[1] There is, however, a very considerable import of articles of clothing, amounting to an average value of over £10,000,000 in the two years 1936 and 1937.

The clothing manufacture is widespread in Britain, but there are, as will be seen, certain distinctive and more or less specialized regions. The factors which seem to have determined the localization are the fairly obvious ones—raw material (mainly the textile fabrics), labour supply, provision of power, ready means of transport, and the great purchasing and exporting markets. Some consideration will be given to one or two of these factors in the study which follows.

Raw Materials. It is quite apparent that there must be a general tendency for the clothing industry to gravitate toward the great textile regions of the West Riding of Yorkshire and East Lancashire. This is particularly manifest in the case of the West Riding, where Leeds stands out quite easily as the leading town in the clothing industry in the provinces. In one of the ablest and most reliable of the trade directories there are 120 clothing manufacturers listed under Leeds for the year 1928. This is an example of modern industrial expansion of an ancient industry. Lord Clarendon, writing in the middle of the seventeenth century, refers to Leeds, Bradford, and Halifax as "three very populous and rich towns, depending wholly on clothiers." Some extracts

[1] This is exclusive of boots and shoes, which are also considered in this chapter.

from Defoe's descriptions of Halifax and Leeds have been given already (see Chapter XVIII).

In an article in the *Yorkshire Post*, on the occasion of the Leeds Civic Week, in September 1928, it was estimated that the number of people engaged in the clothing trade in Leeds was about 30,000. Old-fashioned bespoke tailoring, as well as dressmaking, still figures largely in that city, which in these respects retains a large 'county' connexion. The ready-made clothing industry is, however, far more important, and the goods produced are by no means all of the cheap variety. Leeds produces on a large scale goods for some of the best shops in London and other cities, as well as for a considerable export trade, more especially to the Dominions, but also to Belgium, Germany, and the Argentine.

Suits and overcoats for men and costumes for women form only part of the clothing manufacture and output of Leeds. Cloth caps are made on a very large scale; and shirts, blouses, ladies' underclothing, and general hosiery are other important items.

The place which comes next to Leeds in the West Riding is Hebden Bridge, a town on the Yorkshire Calder, not very far from the Lancashire border. Here in 1928 there were no less than twenty-six firms engaged in the manufacture of clothing, a good deal of it still of the fustian, corduroy, and moleskin type, for working men, but also overalls of many kinds and suits and overcoats are now made. Huddersfield also has a very considerable clothing industry, as have Bradford and Barnsley, but on a lesser scale. There are a number of other West Riding towns which have one or two factories.

Across the Pennines there is the great cotton manufacturing region. There the clothing manufacture is on a smaller scale than in the West Riding, but it is still of considerable importance. Underclothing plays a larger part here, as may be expected in the cotton province. Manchester had thirty-six clothing manufacturers in 1928, and a considerable number of cap manufacturers. Wigan makes underclothing on a fairly large scale, and Bolton, Bury, and Burnley on a smaller scale.

Another textile region is Glasgow and district, where

fabrics are made consisting of many fibres; here also is a considerable clothing industry, producing ordinary outerwear clothing, and in addition underclothing and caps associated with the Renfrewshire and Ayrshire manufacture of hosiery, Scots bonnets, and similar articles. Glasgow itself probably makes more caps than any other town in Britain; the district round the town and the Ayrshire region make many kinds of woollen- and worsted-knitted caps, outerwear, coats, jumpers, sweaters, cardigans, underwear, and hosiery.

With another textile region there must be associated the largest hosiery manufacture of all—that is, the hosiery trade which has such a great hold from south of Leicester to Mansfield, in Nottinghamshire.

Every kind of hosiery seems to be made in the factories of the city of Leicester, and the list of makers fills eight pages in Worrall's Directory. Nottingham, Hinckley, Loughborough, Mansfield, and Sutton-in-Ashfield have long lists, though nothing like that of Leicester, and almost every small town and village in Leicestershire and South Nottinghamshire has some share in this phase of the clothing industry of the Midlands.

Markets and Ports. The clothing industry of Glasgow has some relation to the export trade, as well as to the local supplies of textile fabrics and the Scottish tradition of skilled knitting. The immense home market of Glasgow must also count considerably. The latter condition also applies to Leeds and Manchester and the provinces of which they are the commercial capitals.

Liverpool also has a big clothing industry, there being about forty firms listed in 1928, including some makers of waterproof clothing. Liverpool is, of course, conveniently situated near the great cotton industry, and has good railway connexions with the woollen and worsted industry of the West Riding. The excellent port facilities and important railway connexions make Liverpool a great shopping centre.

Bristol is another port which, although far removed from any very great textile region, can draw on the lesser region of the West Country woollens and worsteds. In the main,

however, the clothing industry of Bristol draws upon the West Riding, the Midlands province, and South-east Lancashire for its textile cloths. Bristol is also a great shopping centre of the West Country, and has a considerable export trade in clothing.

London has an enormous clothing manufacture, chiefly located in the City, Spitalfields, Finsbury, Shoreditch, Stepney, Bethnal Green, Dalston, Hackney, and as far afield as Tottenham and Edmonton, where factory sites are cheaper. There is also a share of the industry in the south-eastern district, chiefly in the neighbourhood of the Old Kent Road.

London makes every kind of clothing. Practically all the raw material has to be brought from far afield, but as an offset against this considerable disadvantage there is the largest home market in the world, and also a vast export trade. A considerable share of this London industry is in the hands of Jews, as capitalists, managers, and workpeople. This branch of the industry secures a large share of the trade in uniforms, for the Navy and Army, and for all phases of public service.

Away across the Irish Sea Belfast has a considerable clothing industry. This is associated with the local supply of woollen goods, and with the demands of the town's own population. Belfast is also the large shopping centre for the greater part of the counties Antrim, Down, and Armagh, and now possesses the commercial advantage which always accrues to a capital city which is also a port and an industrial centre.

There are many other towns, scattered over almost the whole of Great Britain, which have a clothing industry of more than local importance. A mention of their names must suffice: Aberdeen, Crewe, Nantwich, Dudley, Birmingham, Walsall, Nuneaton, Kettering, Colchester, and Plymouth.

Some Special Kinds of Clothing

Hats. Hat-making was once a widespread industry; but within the last hundred years or so it has become more and more localized, until the towns in which it may be reckoned

an important industry can be counted on the fingers. The most important district is in the extreme corner of South-east Lancashire and the contiguous parts of Cheshire. The places most concerned are Manchester, Stockport, Hyde, and Denton. Hyde is in Cheshire, Denton is in Lancashire, and Stockport is situated astride the county boundary. Denton is very largely given over to this industry; in the other places mentioned the hat manufacture is one among several industries. Most of the things incidental to the hat manufacture are also made in the district, including linings, hat-bands, hat leathers, and even the specialized machinery. In 1928 there were sixty-six firms listed as hat manufacturers in the district as defined above.

There is no other town or district in the country where the hat industry assumes such importance. London comes next, and then Luton. In the latter town the manufacture of felt and velour hats has grown out of the older straw-hat industry. There were eighteen firms described as hat manufacturers in 1928, but in the same year there were sixty makers of straw hats. There is no other town which is at all comparable with Luton in the straw-hat industry. It is said that the straw of the wheat grown on chalky soils is strong, supple, and light-coloured, and that such straw is eminently suitable for the straw-hat manufacture. Some straw is imported from Belgium and North-western Africa, and this is claimed to be of high quality.

Glasgow is next in order after the above towns and districts, followed by Leeds, Bury (Lancashire), Atherstone, and Bristol. It is of some interest to note that Bury is one of the important centres of the felt industry, and the slipper industry as well as the hat industry may be regarded as associated with the felt industry.

The Slipper Industry. This manufacture, which depends upon felt and light leather, divides its allegiance between the regions where these fundamental raw materials are readily obtained. Leather slippers are largely made in the Leicester and the Northampton regions, and their manufacture in these districts is just a branch of the boot-and-shoe industry. So it is in East London, in the main, and at Leeds.

The very considerable felt-slipper industry of East Lancashire (said to be the biggest of its kind in the world) is directly related to the felt industry, which is important in that region. The main belt of the Lancashire slipper industry stretches from North Manchester, *via* Bury, and culminates in the Rossendale valley, where Rawtenstall, Waterfoot, and Bacup are the homes of a number of large and successful factories given over to that industry. The growth of this industry in Lancashire has probably been influenced by the abundance of cotton waste and of low-grade wool available (the latter from the woollen industry of Rochdale and Bury); this led to the development of a vigorous industry in felt and many kinds of felted cloths.

Boots and Shoes and Leggings. The primary raw material here is leather, but as a rule it cannot be said that the manufacture of boots and shoes has been specially attracted to the neighbourhood of tanneries and leather-works. The most important factor would seem to be trained and skilled labour, and the industry clings to certain regions where there is the traditional skill that comes of long association with a particular industry. The manufacture is predominantly one of the Midlands, with Leicester and Northampton as the chief centres, neither of them in the front rank as leather-tanning towns. Leicester, on the whole, makes lighter boots and shoes, for women's and girls' wear; Northampton, similarly, makes heavier footwear, for men and boys; but these simple generalizations must not be applied too rigidly.

Almost the whole of Leicestershire is permeated by the boot-and-shoe industry; there are about 120 manufacturers listed in Leicester alone. Hinckley is almost dominated by this industry, and in the extreme north of the county there are several factories at Loughborough. A broad belt in mid-Northamptonshire is practically given over to the industry; this belt stretches from Daventry, in the west, across the county, including Northampton, Kettering, Wellingborough, Higham Ferrers, Rushden, Finedon, and Raunds, as well as a number of smaller villages. In that region the boot-and-shoe manufacture is supreme after agriculture. No doubt the early industry depended largely upon

locally tanned hides and sheepskins, and in turn the rich pastures of the Midlands influenced the numbers of the cattle and sheep; but these early factors are now quite subsidiary to others.

There are a few places away from this great Midland region where an old-established industry has refused to be swallowed up in the modern tendency to localize and specialize. Some of these places are East London, Bristol (with no less than forty-eight factories), Norwich (with twenty factories), and Leeds (with thirty factories). Other places, associated with some speciality, or owing their factories to some dominant personality of the past, are Chesham (Buckinghamshire), Liverpool, Kendal, Newcastle-upon-Tyne, and Glasgow. Liverpool and Glasgow fall only slightly short of front rank in the industry.

Gloves. There are two main classes of goods to be considered, fabric gloves and leather gloves. Fabric gloves are made of woollen, worsted, cotton, or mixed fibres; and this industry, as already pointed out, goes along with that of hosiery (see p. 304). The departmental committee appointed by the Board of Trade to consider the position of the textile trades after the War grouped hosiery and fabric gloves together in Section 8 of their report. This branch of the glove industry is naturally located in the Midland region, and the factories are found in Leicester, Hinckley, Loughborough, Ilkeston, Sutton-in-Ashfield, Ashby, Derby, and Coventry. Outside that region there are occasional makers in London, Bideford, Barnstaple, Torrington, and Frome. Fabric gloves are also made in Scotland, at Dumfries, Edinburgh, and in Aberdeenshire; and in Ireland, in County Donegal.

Leather gloves are made of goat-skin, doeskin, and so-called English 'chamois leather.' The latter is usually the inside or flesh side of a split sheepskin, tanned and finished in a peculiar way which gives it a distinctive softness and pliability. The making of leather gloves is mainly localized in a few special districts where the work is well understood and has been handed on from one generation to another; this factor seems to have been more important than the present supply of raw material, though this, no doubt, operated when

the industry was first established in the particular region, and in certain cases operates even to-day.

Probably the place best known to the general public is Worcester, which has had a long association with the manufacture of various kinds of leather gloves; and the industry there has become almost hereditary. Some of the most famous British glove-makers have their factories in that city. Yeovil, in Somerset, has also had a long association with this branch of manufacture, which has gone on in certain firms for generation after generation.

There is a particular part of Oxfordshire where leather gloves are made, the two chief towns being Woodstock and Charlbury. A similar case is that of Sawston, in Cambridgeshire.

Leicester makes both fabric gloves and leather gloves; the former one can readily understand; the latter may require a little explanation. The leather linings of boots and shoes are largely made from the softer and lighter tanned sheepskins. Leicester handles large quantities of such leather, and some of this is used to make special kinds of leather gloves, many of which are fabric-lined, for which that city of varied leather and fabric industries is now well known.

Manchester and the Cheshire town of Hyde, only seven miles away, contains the district so well known for hat leathers. It is not a far cry from the preparation of the outside halves of split sheepskins for hat linings to the preparation of the inner halves for 'chamois leather' gloves; and one is in no way surprised to find a number of firms in this region engaged in the manufacture of the latter articles.

East London's nearness to the leather district of Bermondsey, where all kinds of light leather are available, may account for the glove manufacture of that varied industrial region. The great market of London's shops and the export trade there are another attraction, and account also for the fact that almost every considerable glove-maker in the provinces has a London depot for his wares.

CHAPTER XXVII

THE MANUFACTURE OF FOOD

IN some measure the making of food has followed the same course as the making of textile fabrics and the making of clothing; first it was largely a home industry, then small factories began to deal with it, now the day of the large food factory has come, and with the advent of these factories there has come closer localization and some specialization. Some examples of these developments will appear in the sequel. The subject is so extensive that only certain phases will be touched, rather by way of examples than in any attempt to cover the whole field.

FLOUR-MILLING

Bread is the chief food in most modern industrial countries. In Britain the word 'bread' means 'wheaten bread' to most people. Rye bread is the regular food for many of the working classes in some European countries, but it gradually disappeared from the industrial districts of Britain from about 1845 to 1870, after the Repeal of the Corn Laws. The great increase in the use of wheaten bread came *pari passu* with the opening up to agricultural settlement of the great plains of North America, South America, and South Australia. The local flour-mill, of which there was one in almost every little town, gradually ceased to work, and was either dismantled or was turned over to other work. Flour-mills were then concentrated in the big towns, where good canal and railway transport was available; and then, in the natural evolution of things, the millers began to move to the ports.

At the present time there is scarcely a big town in Britain, especially one which has railways converging on it, in which there are not two, three, or four flour-mills (or 'corn-mills,' as they are frequently called). Selecting almost at random,

and simply by way of illustration, the following towns may be quoted: Chelmsford, Hadleigh, Ipswich, Boston, and Lincoln, in the eastern counties of England; Bedford,

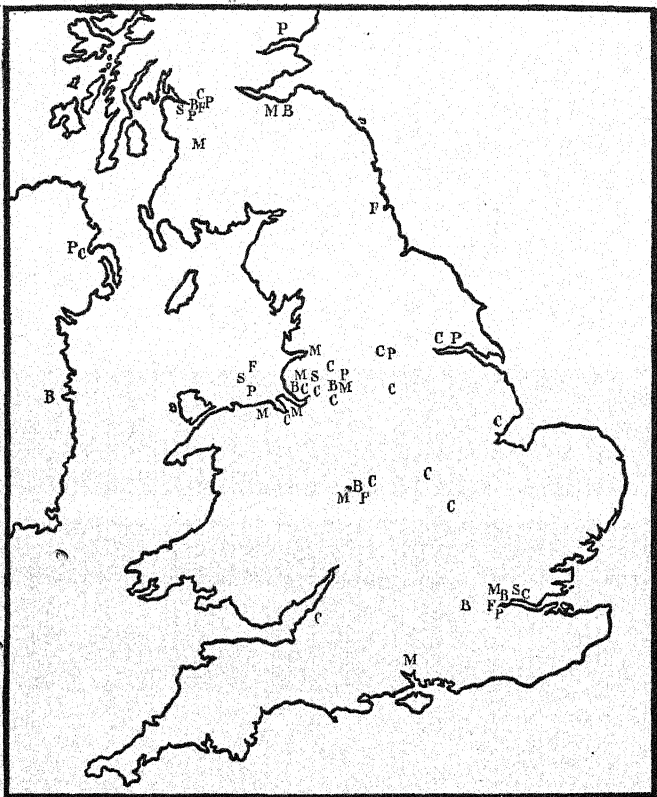


FIG. 30. SOME OF THE MORE IMPORTANT LOCALITIES FOR FOOD MANUFACTURES

C, corn-milling (flour); B, biscuit-making; S, sugar-refining; M, margarine manufacturing; P, preserves and jam-making; F, preserved canned goods.

Leicester, Northampton, and Nottingham, in the Midlands; Derby, Chester, Sheffield, Huddersfield, York, and Stockport, in the North of England. In each of these towns there are four or more flour-mills at work. Two greater centres,

because they are greater centres of population, are Birmingham, with ten mills, and Leeds, with seven mills.

The above are inland towns. At the port towns the flour-mills are numerous and usually large. London and the Thames is, of course, one of the chief centres, second only to Liverpool and the Mersey in the number of mills and the weight of wheat and flour handled. Liverpool, with the Mersey and the Ship Canal region, stands easily first in Britain, and is now the second flour-milling region in the world, being surpassed only by Minneapolis, in the United States. The Liverpool district millers have the pick of the world's markets at their disposal, and they can mix in the correct proportions the soft and cheaper wheat of India, for example, with the white wheat of Australia and the splendid, strong wheat of Canada.

In the order of quantity in a normal year the wheat imports of the Mersey come from the United States, Canada, the Argentine and Uruguay, Australia, and New Zealand; and, far behind these, come Germany, India, the Mediterranean countries, Chile, and smaller shipments from other sources.

It may be remarked here that Liverpool is also the greatest importer of maize into Britain, closely followed by London. The chief source of this maize is the Argentine, with smaller quantities from the United States, South-east Africa, Kenya, India, and Australia.

To return to wheaten flour, the other ports which have a considerable milling industry are Aberdeen, Edinburgh, Newcastle, Hull and the Humber, Bristol, Cardiff, Manchester, Preston, Glasgow (probably next after Liverpool and London), Londonderry, Belfast, Dublin, and Cork.

Factory-made Bread and Cakes

Every town and village has its bakery; and there is also a considerable amount of bread made in the home, especially in some parts of the country where wheat has long been grown, even if its cultivation there has now lapsed. At and near the great flour-milling centres there are many factories

making different varieties of bread, which are usually advertised and sold under some proprietary name. London has many mills or factories of this kind, and almost every great centre of population has its example. The manufacture of biscuits is another big industry which tends to locate itself near the great milling towns. This branch of the food industry is especially concentrated in a few great centres, with, of course, a mill here and there where, as a rule, some speciality is made. London is the greatest centre. Others are Liverpool, Glasgow, Dublin, Manchester, Birmingham, Reading, Edinburgh, and Dundee.

Sugar-refining

The average import of sugar into Great Britain and Northern Ireland for the last four years has been over 42,000,000 hundredweights, perhaps half of which has to be refined here.[1] A hundred years ago sugar-refineries were found in almost all parts of the country, and certainly at every considerable port; there were over a hundred mills in England alone. Now sugar-refining is practically confined to three places, London, Liverpool, and Greenock, in the order named. There are, however (1937), seventeen factories, of which ten are in East Anglia, making sugar from home-grown sugar-beets. Their total output is 8,000,000 cwt., or about one-fifth of the total British consumption. These factories are of limited size, because the crop deteriorates while being collected from a distance. The industry is subsidized by the State.

The products of the British refineries may be grouped as follows: (1) white sugars, with a purity of at least 99·9 per cent.; (2) yellow and brown sugars, for grocers, toffee-boilers, and chocolate-makers; (3) molasses and refined treacle.

Industries closely connected with Sugar

The manufacture of toffee, other sweets, chocolates, etc., depends at once upon sugar; hence these industries are often located near the ports to which the sugar is brought. There

[1] Éire (Ireland) in 1936 imported sugar to the value of £210,000

are, however, famous and long-established factories, bearing names which are household words. Sweets, toffees, and chocolates are made in very many towns, some of which have a world-wide reputation. In the front rank of such towns are London, Bristol, Leicester, Nottingham, Birmingham, Liverpool, Manchester, Bradford, Leeds, Sheffield, York, Edinburgh, and Glasgow. Other towns which are well known are Halifax, Pontefract, Doncaster, Nelson, Watford, Maidstone, Dundee, and Aberdeen.

Preserved Fruit and Jams

This widespread group is clearly related to three factors: the supply of fruit, the supply of sugar, and nearness to the great centres of population. The towns which have the greatest number of works, and which are well known for these productions, are London, Liverpool, Glasgow, Manchester, Leeds, Dundee, Hull, and Paisley. Very closely related to the ordinary preserves, jam, and marmalade industries is the bottling of fruit and the canning of so-called fruit salads. This is now a considerable trade, carried on in the same towns and districts as the above.

Margarine

The manufacture of this well-known mixture of refined animal and vegetable fats with a percentage of milk fat is mainly in the hands of a few very big producers. The factories show a distinct preference for the neighbourhood of the ports and nearness to the great centres of population. In many cases, and, perhaps, very wisely, the actual works are in the country, near a big town, and the storage and dispatch warehouses are in the town itself. Greater London, Southampton, Birmingham, Liverpool and Birkenhead, Manchester and Hyde, Preston, Aber (North Wales), Kilmarnock, Glasgow, Mauchline (east of Ayr, south of Kilmarnock), and Cork are some of the best-known places where margarine is manufactured.

There is a large import of margarine, mainly from the

Netherlands and Germany. The weight of the margarine imported from the Netherlands per annum is in the neighbourhood of 46,000 cwt. This import is handled at London, Hull, Newcastle, Leith (Edinburgh), Liverpool, Manchester, Glasgow, Bristol, Belfast, and Dublin. Manchester is a great distributing centre of both imported and British-made margarine.

Preserved Meats, Fish, etc.

The preparation of various 'preserved foods' is now a considerable and apparently a growing industry. Tinned 'sardines,' lobster paste, smoked and dried fish, factory-made meat-pies, sausages, potted meats, all these are well-known and common examples. The manufacture of these preserved foods is carried on at the ports and in the big cities, as well as in scattered factories in the country. As a rule, these factories have made a reputation for some speciality which has become well known, and a fairly steady demand has been built up by advertising and by the reliability of the product.

The places where most of the factories are found are London, Liverpool, Glasgow, Newcastle, Aberdeen, Birmingham, Grimsby, Hull, and Yarmouth.

Miscellaneous Patent and Proprietary Foods

In the neighbourhood of every big city, and perhaps more especially in the outer suburbs of London, one may see by the railway-side or roadside factories which have familiar names. Some specially prepared foods, either for children or invalids, or claiming to have some special digestive property, are made there. Most of these foods are mixtures of such substances as dried milk, milk sugar, ordinary sugar, powdered cocoa, malt extract, in some cases obviously mixed with such cereals as ground whole wheat, oats, cornflour, etc.

Some of the more popular of these 'foods' demand large factories and employ considerable numbers of people, chiefly girls. They constitute a sort of 'side-line' to the great food industry of the country, and no doubt a highly profitable one.

TOBACCO

The tobacco manufacture may be considered here. It is, again, largely attracted to the ports and the great cities, where supplies of relatively cheap labour are available. London is a very great centre, where there are a few great factories and a number of small manufacturers and blenders. Bristol, Liverpool, Glasgow, Edinburgh, Manchester, Nottingham, and Birmingham are other big centres for tobacco manufacture; and there are many smaller factories scattered over various parts of Great Britain.

Belfast has one of the biggest tobacco factories in the world, and Dublin is also an important centre of the industry.

All the tobacco is imported, the chief sources being the United States of America, the West Indies (especially Cuba), Brazil, the Philippines, and Asiatic Turkey, outside Europe. In the latter continent the chief contributors are Italy, Greece, Bulgaria, Germany, Hungary, and Russia. The amount grown in the British Isles is negligible.

The British Empire has paid much attention to the production of tobacco within recent years, and has not only secured an increased share of the world's trade, but the tobaccos produced have achieved a high reputation. In 1925 of the tobacco cleared from warehouse for home consumption in Great Britain the proportion from Empire sources was about 10 per cent.; this had increased to 16½ per cent. in 1928 and over 17 per cent. in 1929. The value of the latter amount must have been in the neighbourhood of £3,000,000. The increase in Empire production of tobacco within ten years may be put in another way. In 1919 the weight of Empire-grown tobacco cleared from warehouse for home consumption was slightly over 1,500,000 lb., in 1924 the amount was very nearly 12,000,000 lb., while in 1929 it was nearly 27,000,000 lb. The most important Empire exporters to Britain are Nyasaland, India, Southern Rhodesia, and Canada; on a smaller scale are Northern Rhodesia, British North Borneo, the Union of South Africa, Cyprus, Kenya, and the British West Indies.

CHAPTER XXVIII

PRINTING, BOOKBINDING, AND PUBLISHING

THE output of newspapers, magazines, journals, books, and printed stationery in Britain is so colossal that it is thought advisable to include a brief chapter dealing with the printing trade. The paper and printing trades employ over 400,000 people, and the industries are widespread.

There can be very few even small towns in Britain where a printing-works is not found; and in nearly every town a local newspaper is printed and published. In towns of a hundred thousand people there are usually two or three local newspapers, and in towns of half a million or more there are newspapers with a national reputation, and in certain cases with a worldwide reputation. The small town is satisfied with its weekly paper; the town of medium size has its twice-weekly issue; the big town has one or more dailies.

London is the great headquarters of the British newspaper. Not only are the editorial, the advertisement, and the management offices of the great London dailies there, but almost every provincial paper of some standing has a London office. A journey through Fleet Street brings to notice the names of newspapers from every part of the British Isles.

Some London newspapers publish a Manchester or other provincial edition also, and at least one great provincial paper publishes a London edition.

The great centre of the newspaper industry is Fleet Street, in the west of the City of London, and in the streets, lanes, alleys, and courts off Fleet Street.

London is also the great centre from which magazines and weekly and monthly journals are issued. The region about Fleet Street, and the neighbouring part of the Strand district, with Kingsway and its offshoots, is the home of the magazine

of all classes. The publishing of magazines is such an immense business now that it overflows into Bloomsbury, Soho, Covent Garden, and Westminster, on the one hand, and toward the centre of the City on the other. Many technical, commercial, shipping, and financial journals have their homes in the City, round and about Leadenhall Street, Gracechurch Street, Fenchurch Street, the Minories, etc. Some of these are printed in the outer ring of Greater London.

The London daily newspapers are printed in the Fleet Street quarter, but this is not so often the case with the magazines and the journals. Many of the illustrated weeklies are printed at such places as Watford, St Albans, Harrow, Woking—that is, in the ring of towns round and near London.

London is the centre of the book-trade also, and there most of the great publishing-houses have their headquarters. There are colonies of book-publishers in certain well-defined parts of London. An old-established one from which many have migrated in recent years is the Paternoster Row, Old Bailey, and Warwick Lane district; another region is from Fetter Lane to Drury Lane; while there are others in the neighbourhood of St James's Street and St James's Square, south of Piccadilly.

The printing of books for these London publishing-houses is done at places sometimes far afield; Plymouth, Southampton, Oxford, Cambridge, Guildford, Woking, Watford, Letchworth, Frome, Bath, and Aylesbury are Southern towns which engage in book-printing. Many books published in London are printed in Edinburgh, Glasgow, and Aberdeen.

Many towns specialize somewhat in certain types of printing, even though their printing-trade is overshadowed by other industries. Watford, for example, turns out very cheap books by the million, on the one hand, and the highest class of colour work and engraving on the other. One of its firms specializes in very high-grade 'process engraving.' This specialized printing is widespread in the nature of things, and in mentioning a few places it must not be understood that particular types of work are confined to these places. Some noteworthy examples are Truro, Fakenham,

Reading, Bath, Hyde, Oldham, Newton-le-Willows, and Otley.

One must not forget Oxford and Cambridge, among the places famous for high-grade printing and publishing. The University Press of each of these towns has its London house also.

A directory of the printing-trades would almost give one, at first sight, the impression that the volume of printing done is roughly proportional to the size of the towns, but on consideration this is found not to be the case. The printers of Liverpool fill two and a quarter columns of Stubb's *Directory*, those of Birmingham a like amount, and those of Manchester two and a half columns. These great centres have each a very large printing industry; their great newspapers—in the case of Manchester and Liverpool their University Presses—and the demands of a great trading community explain the long lists in the directories. Neither Glasgow nor Edinburgh have anything like so long a list, but the actual amount of printing done there must be enormous. Educational printing is done on a great scale at both places. London's list of printers occupies fourteen and a quarter columns in Stubb's *Directory*.

Aberdeen, Preston, Nottingham, Derby, Brighton, and Dublin have well-known printing-works which have a national reputation. Newcastle, Leeds, Bradford, Sheffield, Bristol, and Belfast combine a vast amount of popular printing with much specialized work, and each town serves the needs of its own busy commercial district and also turns out work with a much wider circulation.

Newspapers, magazines, journals, and books have been specially mentioned. It should not be overlooked that the demands on the printing industry go far beyond these. Certain firms in different parts of the country specialize in all sorts of odd things; one printer makes a speciality of bus- and tram-tickets, another gives particular attention to cigarette cards, a third is noted for fixture cards for football, cricket, and other sports clubs. There are labels, posters, notices, time-tables, calendars, diaries, invoices, bills, catalogues of great variety and purpose, Christmas, New Year, and

birthday cards, bank cheques, postage stamps, banknotes, and still a host of other things to be printed; and, finally, every trade has its particular printed forms, work-sheets, time-bills, employment cards, etc.

The highly specialized and very wonderful machinery used in the printing industry is largely made at Glasgow, Manchester, Leeds, Otley, Nottingham, and London.

SECTION E

POWER AND TRANSPORT

CHAPTER XXIX

POWER IN BRITISH INDUSTRY

THE chapters dealing with the separate industries which are carried on in Britain have been dealt with mainly from the point of view of a geographer. There can be little dispute about the major facts of development and distribution—matters which come within the province of the geographer. There is, however, some room for difference of opinion in the subject-matter of this chapter, and the writer has endeavoured to be quite fair where controversial matters have inevitably been touched.

The goods in British shop-windows have been dug from the ground or made in the factory. (Home or domestic industries are omitted for simplicity of treatment.) These mined and manufactured articles have to be sold either at home or abroad, and whether the goods are for the home market, the Empire, or foreign markets they must be attractive in appearance, good in quality, and reasonable in price. It is the duty of British industry to achieve these results.

It is a commonplace to say that the location and development of an industry depend upon a series of interrelated factors—the supply of raw material, the availability of power, the means of transport, the presence of good markets, and the labour supply.

Under modern conditions the price of raw material tends to become international. Japanese merchants bid against those of Britain and the United States in the wool-markets of Sydney; Italy enters the field and bids side by side with Germany against British buyers of Egyptian cotton; the groundnuts of West Africa and the cottonseed of the United

States or of Egypt are as likely to be bought by Marseilles as by Hull or Liverpool. The price of raw materials is no longer a great factor in competitive efficiency among modern industrial nations.

The net value of labour tends in the same direction. The party politician is much given to exaggerating the advantages of low wages and long hours in competitive production. It has been pointed out already how in a comparison of Lancashire and Japan, producing similar classes of cotton goods, the former with short hours and comparatively high wages, the latter with long hours of work and low wages, the Lancashire labour was relatively the cheaper of the two. The same result has been seen over and over again when it has been possible to make fair comparisons. It should be noted that in the Lancashire cotton industry payment is by piece-work wherever possible.

It is not suggested that the cost of labour is of no moment; it does matter, but it matters very much more when it is considered along with efficiency. Labour (the human element) is the brains and nervous system of industry; it thinks out, controls, and directs. To continue the metaphor, the heart and the life-blood of industry is power. The brain and the nervous system of the organism cannot function properly if the bone and muscle of industry (the machinery of the factories) be not supplied with power. The supply of power is a great problem of British industry now, and will be more so in the immediate future; power efficient, cheap, and well distributed.

The Chief Sources of Power

There are three chief ultimate sources of power available for modern industry, *falling water*, *coal*, and *oil*. Peat and timber, though important locally, may be omitted here as of little value in Britain to-day.

Water-power. This has attracted so much attention in recent years that it must be considered here. There is no doubt that the immense development of water-power in Canada, France, Italy, Switzerland, Norway, and Sweden within the last twenty years or so has cut down British

exports of coal. It does not follow at all that Britain can cut down her own home needs in like proportion. Coal is not at all likely to be displaced by water-power to any very serious extent. Water-power is mostly used through electricity—that is, the energy of falling water is made to generate electricity, and this in turn is used to produce mechanical power or light or heat. In the year 1937 the Electricity Commissioners stated that of the electricity generated in Great Britain 95·62 per cent. was produced directly from steam and 3·27 per cent. from water-power. The electricity generated from falling water was thus small.

It does not follow that the above represents the full capacity of water-power in Great Britain. Various authorities have made calculations of the total water-power resources, and the most liberal estimates go up to about 10 per cent. of the present capacity of public electrical supply stations. Unless there is some revolutionary discovery made in the immediate future British industry cannot hope for much accession of cheap power from falling water. Let not this conclusion be misunderstood or misapplied; every available source of electricity from falling water should be called upon when and where it is needed and when the project or scheme is economically sound. The contributions of Dolgarrog or the Falls of Foyers or the Shannon, in Ireland, and other smaller sources are not, of course, to be despised.

There are not so many stages in the production of electric energy from water-power as in the case of the other sources. The falling water produces controlled mechanical power immediately, and this in turn is made to generate electrical energy. The over-all efficiency of plants may be as much as 80–85 per cent. of the theoretical, which predisposes one in favour of water-power. Efficiency is not the only consideration, however, for the initial capital expenditure for a hydro-electric scheme may be very high. There are reservoirs with expensive dams, to be constructed, conduits, and in some cases long-distance electrical transmission cables, to deliver the energy where it is required. On the other hand, a coal-fired steam electrical station may be located near the place where the electrical power is needed.

Oil. Up to the present time this term usually means some form of petroleum, or else combustible oils obtained from shale distillation. Practically all the former has to be imported, and is too dear for the purpose of generating electricity on the big scale; of the latter the quantity is not great enough to affect the situation very much. About ·26 per cent. of the total electricity generated in the year 1937 was produced from oil-engines. In Britain, at any rate, there is not much probability of any great increase in this direction—namely, through electricity. There is a large import of petroleum, but it is chiefly used in the internal-combustion engines of the petrol motor for transport; it is considered too expensive to be widely used in the big factory for power purposes. The chief ports are Swansea, Hull, and London.

Coal. This is the general fuel used in Britain, and from it most of the power needed in the industries of the country must be produced. James Watt revolutionized the world when he developed the steam-engine. For some decades the Briton worked at high pressure, and he not only made steam-engines for the industries at home, but he also supplied the world. The new power was wonderful in itself, and it had wonderful results. It very soon revolutionized almost every form of industry, and caused production to go up by leaps and bounds. In the new enthusiasm bad slips were no doubt made, and in the glamour of conquest the standard of life of the workers was too often overlooked, and the modern industrial town was allowed to grow unguided and unchecked.

Steam has played its great part, but it seems that now it needs an ally. Steam produced from the burning of coal must be made less expensive and more efficient; electricity is the modern ally for this purpose. It would seem at first sight that this involves too roundabout a process, three stages being necessary. The chemical energy present in coal, stored up from past geological ages, is first converted into heat in the making of steam—the first stage. The latent heat of steam is then converted into mechanical energy by the use of the steam-engine—the second stage. The mechanical energy is then converted into electrical energy in the dynamo—the third stage. At each stage there is inevitable loss; of

the potential energy present in the fuel about 25–32 per cent. appears as electrical energy under the most favourable conditions. The case is not so bad as it would appear at first sight; the highest efficiency in energy transformation is not the only consideration. The bald fact is that the coal is available, the other primary sources of energy are not.

The problem for British industry is to increase the efficiency of the engines employed, as a whole, and thus to reduce the cost of electrical power. About 7 per cent. of the coal consumption of the country—about 13,600,000 tons of coal—is used for generating electrical power, and this is only producing about half the total electrical energy that it could produce under the best modern conditions. This is what makes electricity dear. Improvements recently brought about allow electricity for power to be supplied in bulk to factories at less than ½*d.* per unit.

An analysis of that which has been holding back many British industries is afforded by some tables given in Mr Hugh Quigley's book on *Electrical Power and National Progress*, published in 1925. The average price obtained per unit sold by five great power companies of the industrial North was 0·85*d.*, which, considering the price of coal at the time, was a fairly good result. Eight great municipal undertakings of the North averaged 1½*d.* per unit, while four London power companies averaged 3·22*d.* per unit. This was in 1924; within the last few years there have been many reductions and at least one increase. Electricity is now being used more and more, which, owing to bulk demand, has lowered the cost of supply in some areas. In the year 1937 the total amount of electricity generated in Great Britain from 424 stations was 24,314,845,292 units.

To effect the economies suggested there will need to be a replacement of small and inefficient stations by big stations of larger capacity, all interconnected. Such improvements are being prepared by the Electricity Commissioners appointed under the Government. Ten regions have now been planned: Central, South, and North Scotland, North-western, North-eastern, Mid-east, Central, East, South-eastern, and South-western England and South Wales. The scheme for North-

western England and North Wales issued in 1928, and published in the newspapers and technical journals, may be taken as a type; it includes Cumberland, Westmorland, Lancashire, parts of Cheshire, Derbyshire, and Shropshire, Flintshire, Denbigh, Merioneth, Anglesea, Carnarvon, Montgomery, and part of Cardigan. Of the present very large number of electrical stations twenty-four will remain in operation, and two new ones are proposed, one at Clarence Dock, Liverpool, the other probably at Carrington, on the Manchester Ship Canal.

The Central Scotland region, which has been before the public longer, may be noticed from another point of view. In 1926 there were 147 generators in the region; it is proposed to reduce the number to 37 by 1941. The average capacity of each generator was 3300 kilowatts; in 1941 the average capacity will have been brought up to 23,200 kilowatts. The aggregate maximum demand on the stations was 290,000 kilowatts in 1926. There are similar changes in view in the other regions for which schemes have been prepared.

The Central England scheme extends from north-east of Mansfield to south-west of Tewkesbury, and from north-west of Leek to Fenny Stratford. It includes the counties of Leicester, Stafford, Worcester, Warwick, and Northampton and portions of seven other counties. It covers an area of 7311 square miles, and includes a population of over 5,000,000. The chief towns are Nottingham, Derby, Stoke, Stafford, Shrewsbury, Wolverhampton, Dudley, Birmingham, Worcester, Warwick, Coventry, Rugby, Northampton, and Leicester.

When the new schemes have matured there should be available for industry electrical energy which will not only cost less than coal at present, but will be much more elastic in its application. The long-distance rope-drive will be eliminated, and there will be an individual drive for each machine or small group of machines. This has been achieved already in scores of factories, even with the present comparatively high prices of power.

The clearer atmosphere will be worth a great deal. Many

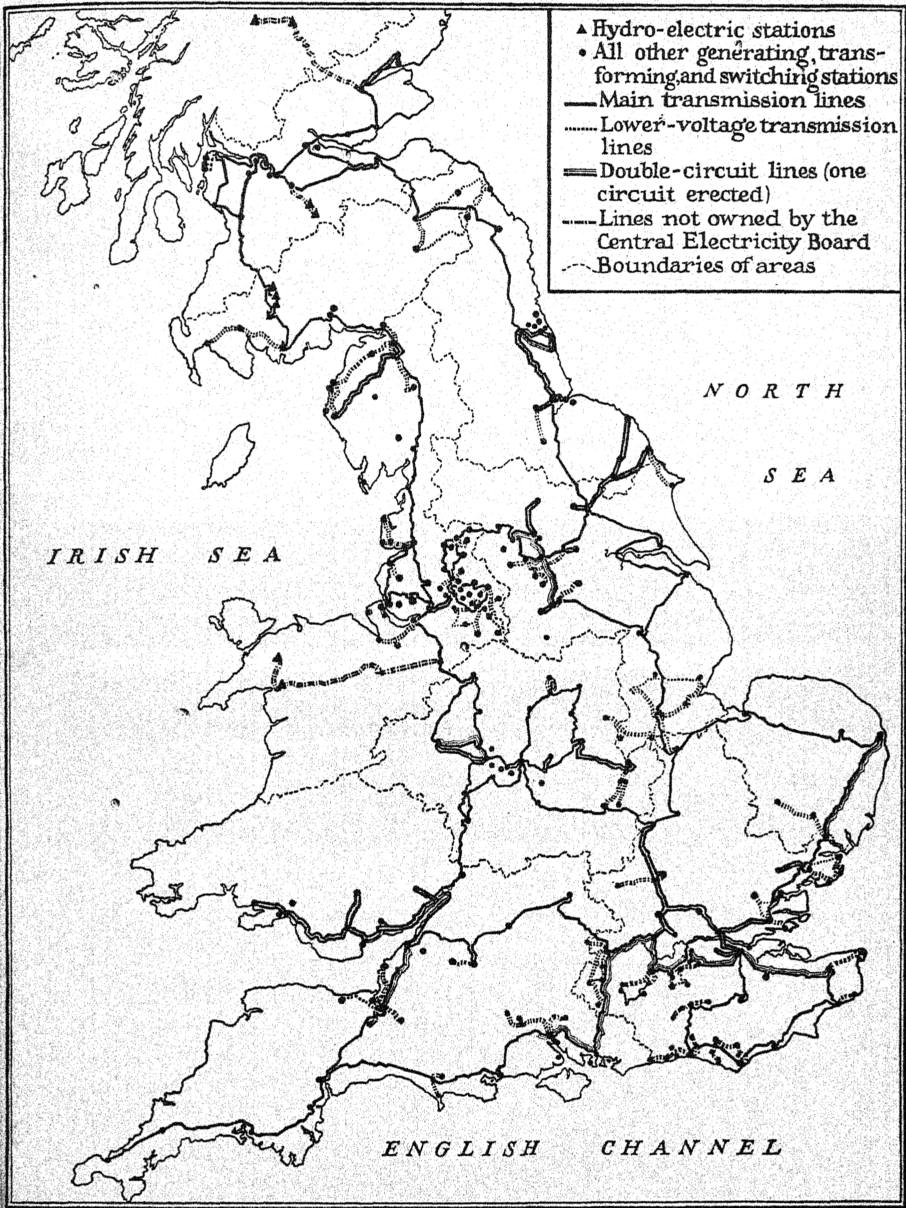


FIG. 31. THE COMPLETED SCHEME OF ELECTRICAL GRID TRANSMISSION LINES AND DISTRICTS

The London area is served by a local cable grid which could not be shown on this scale.

By courtesy of the Central Electricity Board

industrial towns which are too often under a pall of smoke will become as they were seen during the coal disputes of 1921 and 1926, when the Londoner saw the Crystal Palace and the North Downs quite commonly, and not as a comparatively rare event. The worker of all grades, from the directing and research staffs down to the least responsible labourer, will benefit by the clearer atmosphere and by the increased quota of unhindered sunshine. Who can estimate the loss of pure physical fitness which has been caused by the smoky atmosphere this many a generation past?

CHAPTER XXX

TRANSPORT IN BRITISH INDUSTRY

THAT industry depends upon transport is a self-evident proposition. Several times in the study of the different industries in preceding chapters there have been hints of this dependence. Roads, rivers, canals, docks, and railways have been mentioned many times, especially in the discussion of some great industry and its development in a particular region. Ever since the dawn of the great industrial change which marked the beginning of the modern era the development of industry has obviously marched with that of transport; the two have acted and reacted upon each other all through the period. Again, all this has been inferred in the earlier chapters, but a study from the point of view of transport, rather than from the point of view of industry, will now be in place.

The study may well begin in the very early days of the Industrial Revolution. There is, of course, no precise date of which it is possible to say "The Industrial Revolution began now"; great movements and distinctive eras have their roots in the past, and it is only when a number of interdependent and interacting events have played their part can it be said that the new era is fully established. It is often convenient, however, to select some date empirically and begin there; in the present instance the year 1700 makes a suitable starting-point. Many things had happened before that date which had a far-reaching influence on modern British industry, as was abundantly seen in the chapter on the early history of the wool and cotton industries. Still, for all that, 1700 will serve the present purpose, and it will accordingly be taken.

The Act for the Aire and Calder Navigation was dated 1698. When the work was carried out it became possible for barges of considerable tonnage to pass from Leeds to the Humber. This gave a great impetus to the growing trade of the Yorkshire town.

Newcomen introduced the cylinder and piston into the steam-engine, or 'fire-engine,' as it was still called, in about 1705–6; Abraham Darby the First probably made his first successful experiment in smelting iron by means of coke in 1709 or 1710; the "Old Dock" at Liverpool, probably the first enclosed dock ever built, was completed in 1715; the Acts of Parliament for the Mersey and Irwell Navigation and the Douglas Navigation were obtained in 1719–20; John Lombe, who had worked in a silk-mill in Italy and learned the secrets of their processes, started the first silk-mill on the banks of the Derwent, at Derby, in the years 1715–18; John Kay of Walmersley, near Bury, invented his 'flying shuttle' in about 1733; Lord Townshend began his famous experiments in agriculture at Rainham, in Norfolk, in 1730, and introduced the well-known Norfolk rotation; and Jethro Tull published his book on husbandry in 1733. These experiments, inventions, and innovations definitely mark the dawn of a new era.

The opening of the "Old Dock" at Liverpool, and the attempts to improve the Aire, Calder, Mersey, Irwell, and Douglas for navigation, are definite signs of the increasing attention given to transport. And it was high time, if industry was to make any progress at all. The usual mode of travel up to this time, and during the early part of the eighteenth century, was on horseback; at least, it was so for those who could afford it. "The rich rode; the poor walked" was a terse summary of the times. There were, of course, the early stage-coaches, some of which had been running from the middle of the seventeenth century; but they were very uncomfortable, unreliable, very slow, and many of them did not attempt to run in winter. In 1700 the coach from York to London took a week to complete the journey; Exeter was five days from London; Edinburgh was about a fortnight distant.

Roads and Bridges

Meanwhile how did merchandise fare in these early days? The pack-horse was the usual means of land transport of goods from one place to another. Wheat, oats, rye, and wool were taken to the market-town in panniers, and coal was

carried from the pit to the farmhouse, the gentleman's home, and the forge in the same way. The pack-horse roads may still be seen in many parts of the Pennines, and here and there one may notice the narrow, high-pitched pack-horse bridge, which was obviously never intended for vehicular traffic. The Pack Horse Inn, the Wool-pack, and other names are not yet extinct in many parts of the North Country. Nor did the pack-horse disappear until quite recent times. The writer distinctly remembers seeing a train of pack-horses which had come 'over the hills,' bringing lime from the lime-kilns at Clitheroe or Lothersdale to the farmers and builders in the district. This would be about 1867–70. Old customs died hard in some of the remoter districts of the country.

In the first half of the eighteenth century there was some effort to improve the turnpike roads. The first Turnpike Act was dated 1663, but little progress had been made in road improvement before the time of the great road-makers, from 1760 to 1830. In many parts of the country the people were violently opposed to the extension of the turnpike system, and many of the toll-houses and toll-gates were destroyed by angry mobs, especially between 1750 and 1760. The result was that some roads received little attention and attempts to repair them won little sympathy from the people of the districts through which they passed.

The state of the roads is described in graphic and forceful language by many people of those times, notably by Arthur Young, in his account of tours through the country. "Of all the cursed roads that ever disgraced this kingdom in the very ages of barbarism, none ever equalled that from Billericay to the King's Head at Tilbury." This he wrote of a road in Essex; and he is as dissatisfied with a road in Suffolk, the turnpike road between Bury St Edmunds and Sudbury. "For ponds of liquid dirt, and a scattering of loose flints just sufficient to lame every horse that moves near them . . . render at least twelve out of these sixteen miles as infamous a turnpike as ever was beheld." And lest other parts of the country should by any chance become conceited, he distributes his caustic remarks quite impartially almost everywhere. Of the turnpike road between Chepstow and Newport

he says: "But, my dear Sir, what am I to say of the roads in this country! the turnpikes! as they have the assurance to call them and the hardiness to make one pay for? . . . Mere rocky lanes, full of hugeous stonnes as big as one's horse and abominable holes." But perhaps he reserves his choicest epithets for the roads in Lancashire. Of the road from Wigan to Preston he writes: "Let me most seriously caution all travellers who may accidentally propose to travel this terrible country, to avoid it as they would the devil," and much more of the same caustic character.

It may be pointed out that Defoe, who visited a good deal of the same ground, and travelled many of the same roads, forty years or more before Young, is not nearly so denunciatory. In the Appendix to volume ii of his *A Tour through England and Wales* he describes with some care the improvements which were being effected by the Turnpike Commissioners:

> The benefit of these turnpikes appears now to be so great, and the people in all places begin to be so sensible of it, that it is incredible what effect it has already had upon trade. . . . Even the carriage of goods is abated, in some places 6*d*. per hundredweight, in some places 12*d*. per hundred.[1]

But even Defoe points out how difficult and dangerous the roads were in many places, especially through and across the Mesozoic clay vales of Central and Southern England.

Between the years 1760 and 1774 there were 452 Acts of Parliament passed which had to do with the making and repair of highways. Highway Boards were called into being, and these became very active near London and the larger provincial towns, and in regions where industry was already developing rapidly. This activity, in the long run, called forth a new generation of engineers. One of the Acts of Parliament mentioned above authorized the construction of a turnpike road between Boroughbridge and Harrogate. This road passed through Knaresborough, and it was here that the famous Blind Jack (John Metcalf) lived. Metcalf knew well the need of good roads, and he foresaw a whole series

[1] Everyman edition, vol. ii, p. 129.

of such roads in the industrial North. He offered to lay down three miles of the proposed road, and he received the contract for the job. He did the work to the satisfaction of the surveyor, and this led to his becoming the recognized road-maker of the West Riding and East Lancashire. For about thirty years he gave himself over to this work, and he planned many of the roads between the rapidly growing towns of these regions: Bradford and Halifax, Huddersfield and Oldham, Bury and Blackburn, Burnley, Colne, and Skipton, are examples. Metcalf's roads were of incalculable value to these industrial regions in those marvellous years of development of the mining, engineering, and textile industries. Some of his roads were afterward straightened out, and new stretches were substituted in the 'new road' era of 1810–30, but many of Metcalf's roads settled the routes for much of the tremendous road traffic that passes across those busy industrial counties.

THOMAS TELFORD

The great engineers took interest in roads in other parts of the country; and in the early part of the nineteenth century two other famous men introduced new methods and new ideas; these were John Loudon Macadam and Thomas Telford, both natives of the South of Scotland. Macadam taught how to make roads with a more even and lasting surface, and the name of his method has passed into the English language; Telford and his followers taught how to take advantage of gradients and to adapt roads to the contour of the country. Their work was done by the early thirties of the nineteenth century, and, in the main, little alteration was made to or needed for many of their excellent roads until the present period of road alteration and making of new roads began.

Some of Telford's more famous road-works were the improvement of the London–Holyhead road, and with it the building of the Menai Suspension Bridge, the Carlisle–Glasgow road, and a network of roads in the difficult country of the Western Highlands of Scotland. The work of Metcalf, Macadam, and Telford was of tremendous value in the rapid expansion of British industry in the nineteenth century.

Pari passu with the development of roads was the building of bridges. There were, of course, many historic bridges, some of which had stood since Norman times, others were of the later Middle Ages, and yet others had been built in early modern times. With the rapid development of industry and the increasing needs of transport and travel there came in the eighteenth and nineteenth centuries another great era of bridge-building. One of the most interesting of the modern bridge-builders was a self-taught genius, similar to Metcalf and Brindley; he was William Edwards, a native of South Wales, born in 1719. His most famous work was the Pont-y-Prydd, over the river Taff, but he and his sons built scores of other bridges in Wales and in the English counties near the Welsh border. Bridge-building had become almost a lost art in Britain; William Edwards revived it, and his work played an enormous part in the industrial development of Carmarthenshire, Glamorganshire, South Breconshire, and Monmouthshire.

Other great and more ambitious builders of the road-bridges needed by the rapidly developing industries of the time were Smeaton, the elder Rennie, and Telford. Rennie constructed many bridges, both in England and Scotland, his masterpiece being the beautiful Waterloo Bridge, over the Thames at London. Smeaton built many bridges, and planned many harbours, but his most famous work was probably Eddystone Lighthouse. Telford built the famous aqueducts by which the Ellesmere branch of the Shropshire Union Canal is carried across the Dee and the Ceiriog, but his masterpiece is the famous Menai Suspension Bridge, by which the Holyhead road crosses the Menai Strait. These men contributed no little to the industrial development of their time. They were great and famous men; Rennie was

buried in St Paul's Cathedral, Smeaton received the Copley Medal of the Royal Society, and Telford was buried in Westminster Abbey. All who take interest in, and are proud of, the wonderful history of British industry should honour the memory of such men.

Rivers and Canals

Meanwhile merchants and manufacturers were feeling the need for better transport facilities by water. Liverpool and Manchester, for example, were both growing rapidly; the former was going ahead as a port, the latter as a manufacturing town. Communication between the two was very imperfect, however, and the cost of taking anything from one place to the other was almost prohibitive. Hence the insistent demand that the Mersey should be made navigable and the eventual promotion of the Mersey and Irwell Navigation Act, in 1719. Similarly Liverpool wanted coal from Wigan, but the cost of transport by pack-horse was very great, and across the mosses of South Lancashire there were few good roads. The Douglas Navigation scheme was the solution of this difficulty, and though it does seem a long way round to take coal from Wigan northward to the Ribble estuary and then round the West Lancashire coast to Liverpool, this was cheaper than any other way. These two schemes were a beginning for Lancashire, and they were obtained, as mentioned already, in 1719 and 1720.

Similarly the Aire and Calder Navigation had been pushed forward by the merchants of Leeds, who realized how valuable it would be for the export of woollen goods and for the import of butter, sugar, tobacco, etc.

The Sankey Brook scheme of 1755 was more ambitious; the river was made navigable in parts, but new stretches of 'canal' were made to improve the navigation, and the resultant system was partly river, partly canal. The Sankey Brook flowed from St Helens to join the Mersey near Warrington, and this navigation scheme thus joined these two towns. But the main forward move came in 1759–61, when Brindley, acting as engineer for the Duke of Bridgewater, made the

Worsley Canal. The story of Brindley's triumph has been told a score of times, and it need not be repeated here. The important result, from the point of view of the present study, was that coal from the Worsley coal-pits was now sold in Manchester at fourpence per hundredweight, instead of about a shilling a hundredweight, as formerly. This gave a great impetus to the growth of Manchester, and later, when the steam era dawned, its effect was very marked. The Worsley Canal was little more than ten miles long, but it showed what could be done, and when it was triumphantly opened for barge traffic on July 17, 1761, a new phase of transport had definitely begun.

A perfectly natural step was the extension of the Duke's canal to the Mersey estuary. In itself the problem of transport from Worsley to Manchester was but a trifle; the principle involved was the big thing. Manchester was still much hampered in its trade with Liverpool. Road transport cost about £2 per ton; the cost by the Irwell and Mersey was twelve shillings a ton; but the latter route was tedious and difficult, and frequently barges were held up for some time, either on account of floods or because there was not enough water. The Duke realized what a big opening there was for an assured and fairly cheap route, and he therefore secured an Act for a canal from Manchester to Runcorn. Brindley was again the engineer, and again he overcame all the structural difficulties, while the Duke dealt with the financial difficulties. The level length of the canal to Runcorn was finished in 1767, and opened for traffic along that length; the lock system, which took barges down to the level of the river Mersey, was not completed until late in 1772. On January 1, 1773, a vessel of fifty tons burthen passed through the locks on its way to Liverpool. The Bridgewater Canal was now complete, and the Duke had merited the proud title which appears on his monument in Ashridge Park, Hertfordshire: "The Father of Inland Navigation." Meanwhile the great but eccentric genius Brindley had passed away, in 1772, but not before he had given stimulus to many other canal undertakings.

Many of these other canals were under construction before

the Bridgewater Canal was completed, in 1772, and within a few years what has been called the 'canal mania' had started, a movement which culminated in the years 1792–95. In the years 1793 and 1794 no fewer than forty-five canal and navigation Acts went through Parliament. New canals were planned everywhere, and though many of them seemed likely to succeed, and did, in fact, succeed for a time, there were many which were purely speculative, and were likely to fail from the outset. The coming in of the financial speculator, whose object frankly was to plunder the public, was a national calamity. Thousands of investors lost the whole or a considerable part of their savings, and at the same time great harm was done to the trade of the country.

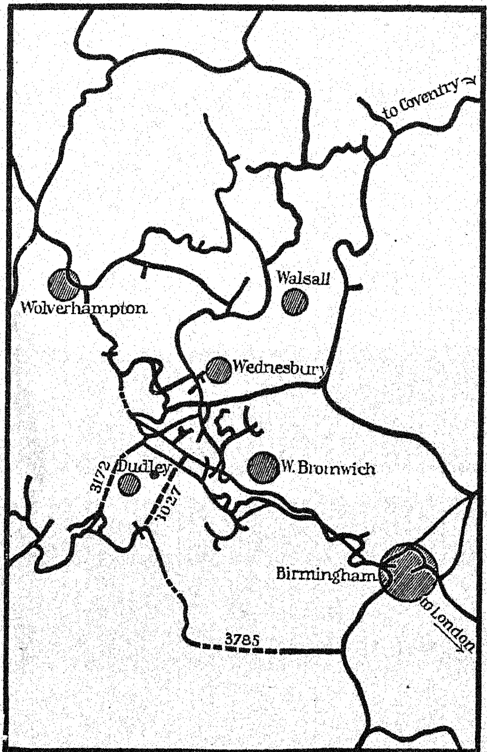


FIG. 32. THE CANALS OF THE BIRMINGHAM-WOLVERHAMPTON DISTRICT

The lengths of the three long canal tunnels are given in yards.

Some of the successful canals not only paid, but paid very well, and these for a time helped on the developing industry of the country very greatly. Unfortunately the prospects of high dividends proved attractive to the 'financiers' again,

and they proceeded to exploit the industries of the country and the general public most mercilessly. Canal shares rose to fabulous heights, and the result was that canals came to be regarded in the eyes of many people not so much as a form of public service, but as a means of making big dividends. One cannot acquit the Parliaments of the times of gross betrayal of the public interest, in that they did not step in and prevent this shameless spoliation. Toward the end of the canal era there were such examples as the following: a £75 share of one canal was selling for £2200 in December 1824, a £10 share in another was fetching £290, and a £1 share in a third was quoted at £45; and there were many more examples of the same order. No wonder that canals came to be regarded as monopolies in which shareholders had vested interests of an extravagant order! Even a broad-minded and public-spirited man such as the Duke of Bridgewater is reported to have said something like the following when viewing the introduction of tram-roads (railways): "We may do very well if we can keep clear of these —— tram-roads."

This abuse of the earning power of canals has influenced adversely the industrial life of Britain even to the present day. The canal proprietors of 1825–40 were so keen to retain their monopoly that they opposed the introduction of railways by every means they could. Thus the promoters of railways were saddled at the outset with excessive costs of Parliamentary proceedings; these costs crippled the early development of railways, and like all such adverse influences their action is not confined to the time concerned.

Railways

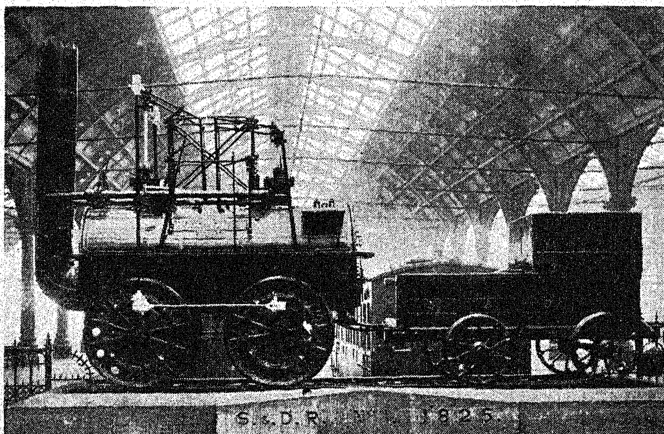
By 1820 or thereabouts traders and manufacturers were becoming impatient with the canals. The natural limitations of canals were obvious enough; they were often short of water in summer, frequently closed by ice in winter. Take the case of Manchester and Liverpool, for example, two towns with a great industrial community where invention and discovery and a rapidly increasing population demanded regular,

reliable, and reasonably cheap transport. There were already two lines of communication by water—the Bridgewater Canal to the Mersey, and the Mersey and Irwell Navigation. Some people suggested a third and, perhaps, a more direct canal; but the obvious objection was that there was not enough water for the two already in existence. Also the proprietors, especially of the Mersey and Irwell Navigation, grossly abused their monopoly. It is said that these proprietors received in dividends the amount of the original value of the shares every alternate year. Then, too, there was often great delay, and goods intended for Manchester often took longer to cover the fifty odd miles from Liverpool than they had occupied in crossing the Atlantic. All this was sure to cause dissatisfaction and impatience, and merchants and others turned to railways as the remedy.

GEORGE STEPHENSON

Railways, though yet quite young, were not altogether new when the Liverpool and Manchester Railway was proposed. The prospectus for the company was issued in 1824; their Bill was carried through Parliament in 1826. George Stephenson was appointed engineer, and the making of the railway was at once begun. Stephenson had already won fame by the second Killingworth locomotive engine, made in 1815, of which he and Ralph Dodds were the joint patentees; this engine introduced the use of horizontal connecting-rods, and also the steam blast, and as his famous son Robert said forty years afterward, it was the prototype of the highly successful locomotive steam-engines of the latter half of the nineteenth

century. It is of interest to mention here that first the promoters and later the directors of the Liverpool and Manchester Railway Company made visits to Killingworth to see the working of Stephenson's locomotive engine. Later, between 1822 and 1825, Stephenson had acted as surveyor and engineer for the Stockton and Darlington Railway, which

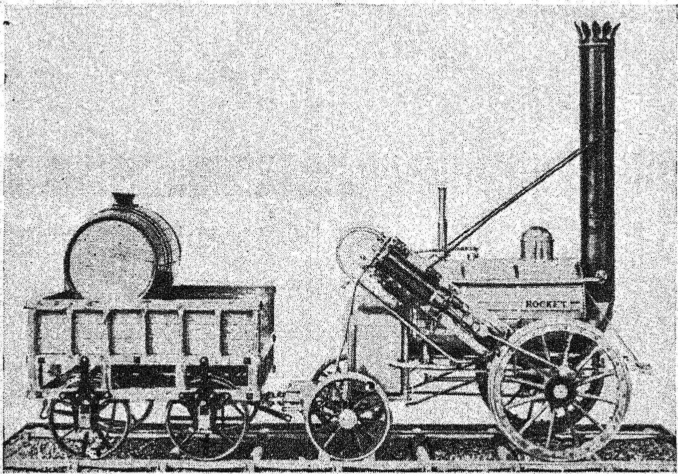


STEPHENSON'S NO. 1 ENGINE AT DARLINGTON

was opened in September 1825. He had proved himself in two directions.

The story of the difficulties and triumphs in connexion with the construction of the Liverpool and Manchester Railway has been told too often to need repetition here. As the railway was approaching completion the question of tractive power had to be decided upon, whether horses, fixed engines, or locomotive engines should be used. Stephenson found himself almost alone in his persistent advocacy of the locomotive; the professional engineers were practically all against him, and public opinion had been prejudiced by all sorts of fantastic stories. Stephenson, however, stuck to his opinion, and eventually won over the directors; and early in 1829 a prize of £500 was offered for the best locomotive engine. The 8th of October, 1829, was fixed for the trial, and four

engines were brought forward to compete at the trials at Rainhill, Liverpool. Messrs R. Stephenson[1] and Company's *Rocket*, made at the works at Forth Street, Newcastle, was the only one which satisfied the tests, and the prize was awarded to Stephenson's firm. The original engine is now in the Science Museum at South Kensington, London.



THE "ROCKET"

Three important results followed from these trials and the work of the four years preceding: the locomotive engine was established as the tractive power for the new railways; George Stephenson was now fully recognized as the greatest locomotive engineer of the day; and his position as a surveyor and engineer of railways was once for all established. A trial train drawn by the *Rocket* was run over the greater part of the railway on January 1, 1830; preparatory work was pushed forward, numerous other trial trips were made, and the line was ready for the public opening on September 15, 1830. The opening was attended by the Duke of Wellington (Prime Minister), Sir Robert Peel (Secretary of State),

[1] The R. Stephenson here was George's elder brother Robert. George had a son Robert also, who was a famous engineer.

Mr Huskisson (one of the Members of Parliament for Liverpool), and many other distinguished people of the day. A sad accident, which caused the death of Mr Huskisson, cast a cloud over what was otherwise a most triumphal opening. Eight railway engines took part in the 'procession,' the first one driven by George Stephenson, the second by his son Robert, and the third by Robert Stephenson senior (the brother of the great engineer). The railway era had begun. There were at the time thirty stage-coaches which ran between Manchester and Liverpool; within a very short time only one of these kept up the journey.

ROBERT STEPHENSON

While the Liverpool and Manchester Railway was in course of construction other railways were started elsewhere, and after 1830 many projects of earlier years were carried out. The promoters of the London and Birmingham Railway brought forward their Act in 1832, but though it passed the Commons it was rejected by the House of Lords, largely owing to the determined opposition of two peers whose estates lay near Watford, and who regarded the proposal with disfavour. The Act was got through in 1833, at an enormous cost. Robert Stephenson was appointed the engineer, and work was at once commenced. The 112 miles of railway were constructed, and the whole line was opened in 1838. This was the first of the great 'trunk lines' from London; the name was changed to London and North Western in 1846, a name which has been in the front rank of railway names for three-quarters of a century.

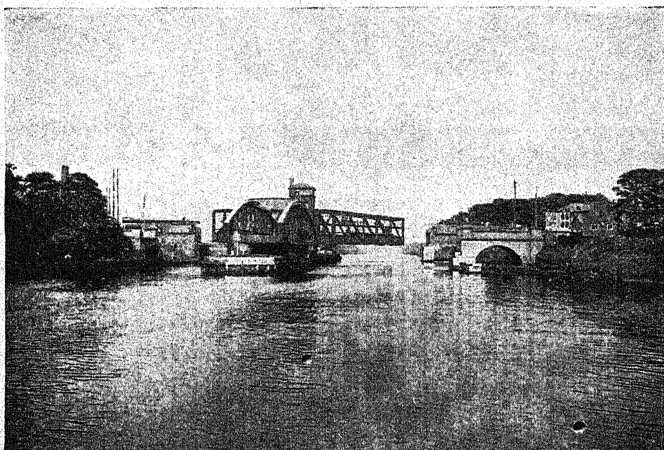
Similarly, at a slightly later date, the Midland Counties Railway was laid to connect up South Nottinghamshire and Leicester, and later became, along with the North Midland

Railway, the nucleus of the Midland Railway, which has also had such a long and honourable history. The London and North Western Railway and the Midland Railway were the two most important systems of railways which were combined to form the London, Midland, and Scottish system, by the Railway Act of 1921. The various lines which after the early days of railways developed into the Great Eastern, Great Northern, North Eastern, Lancashire and Yorkshire, Great Western, and other big systems had practically all started by that great year of Railway Acts, 1845. Just as there had been a 'canal mania' half a century before, so a 'railway mania' came in the middle of the nineteenth century. One of the more serious features of that time was the somewhat unprincipled way in which rival companies sought to invade one another's provinces. Immense amounts of money were thrown away in these inter-railway wars, and the railway companies were crippled for long after, and trade and manufactures, of course, suffered in consequence. Landowners robbed the railway companies mercilessly; it cost an extra half-million sterling to buy off their opposition to the London and Birmingham Railway in 1832–33; and in other districts the same spirit was abroad. The determined opposition of the canal companies was usually overcome by the, perhaps, short-sighted expedient of taking over the canal at an inflated valuation. Most of the great railway companies of the Midlands and the North have been saddled for over half a century with one or more canals which have never paid, and the maintenance of which has been a serious drain on their revenues.

It is readily seen from the above that the railway companies were weighed down from the very outset with heavy financial burdens which they ought not to have had to bear. This should be remembered when the failure of railways to render service to industry, corresponding to the needs of the times, is being discussed.

All the great railway companies, and nearly all the great main lines, were in full working order by 1870, and perhaps the years from 1880 to 1900 may be regarded as having seen the climax of railway activity and railway success. The great

companies were already tired of running up bills of expenses by fighting one another; the battle of the gauges had gone in favour of Stephenson's original gauge, henceforward to be known as the 'standard gauge,' and the rival companies had learned to give and take in the matter of running trains over one another's rails. The British railways were now the admiration of the world. But their directors had not read



BARTON AQUEDUCT

the judgment on the canals, or had forgotten it, and it would seem that their very success was a danger to them.

The railways, with their main lines catering for long-distance traffic and their exceedingly complex networks of local lines in the industrial regions, lost some of their early elasticity, and by their very magnitude became cumbrous. Staffed by conscientious and brilliant men in the higher ranks of the service, the demands of the internal working of the vast machine reacted to external stimulus only with difficulty, and the complaints of 1820 were heard again. Goods were a long time in transit, and traders and manufacturers did as they had done two generations earlier; they looked sympathetically at alternative methods of transport. The dissatisfaction of the business community of Greater Manchester

was the greatest motive behind the Manchester Ship Canal; that great and expensive experiment in internal water trans port. This canal stands alone among inland waterways. It was commenced in 1887, and was opened in 1894; and it has cost about £17,000,000. The canal is 35½ miles long from Eastham to Salford, its minimum depth is twenty-eight feet, and it has a minimum bottom width of 120 feet. There are five sets of locks, and there are eight large docks at the Manchester-Salford end of the canal. Number 9 dock, the largest, is 2700 feet by 250 feet. Steamers with a dead-weight capacity of 15,000 tons use the canal regularly. One of the most wonderful engineering works ever achieved is the Barton Aqueduct, by means of which Brindley's original Bridgewater Canal is carried over the Ship Canal. The aqueduct is made to rotate, and so allow a free passage for ships on the latter canal. This great canal was a part of Lancashire's answer to the inability of the railways to do better. Now the West Riding is talking quite seriously of a similar canal to connect Leeds with the Humber.

Between 1890 and 1900 traders and manufacturers began to experiment with through traffic on the roads, and not simply between works and railway sidings, or between railway depôt and shop. The coming of the internal-combustion engine and the development of the motor-wagon in the very early part of this century soon altered the whole position. A Burnley manufacturer, for example, now sends his woven cloth to Manchester by road, and the journey takes perhaps two and a half hours. The cloth is delivered into the Manchester warehouse, and the motor-wagon begins its return journey, going *via* Oldham, or Royton, or Rochdale, picking up a load of yarn from the spinner or doubler, and arrives at Burnley in the late afternoon. Notice what this transport would mean by railway. The cloth would be collected by the railway company's wagon and taken to the goods warehouse or goods sidings; here it would be transferred to a railway goods wagon, and then would start on its journey to Manchester. From the railway depot at Manchester or Salford the load of cloth would be transferred to the Manchester warehouse. At the very best there are

two handlings of the cloth, and consequent loss of time. Probably conditions have improved recently, but at one time, a few years ago, the time occupied by the transport from the mill at Burnley to the merchant's warehouse often amounted to a week; meanwhile the money representing the value of the cloth was lying idle, which is a serious condition in such a heavily capitalized industry. Obviously the railways are greatly handicapped for such transport; and a vast amount of it, all over the cotton-manufacturing region of Lancashire, has left the railway, and now goes by road.

THE "CORONATION" TRAIN

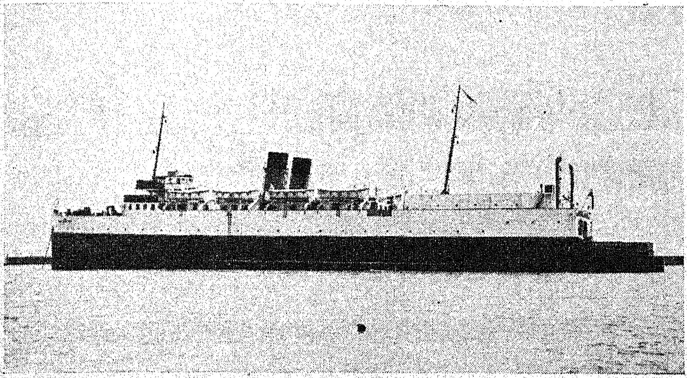
By courtesy of the London and North-eastern Railway

Again, take a case from a totally different part of Britain. A Watford printer must deliver finished magazines or weekly illustrated papers to a London publisher, or catalogues to a large multiple shop in London. Their own delivery motor-vans can transfer the parcels from the printing-works to Fleet Street or Kingsway within two hours at the most. Here again the railways cannot hope to compete, as is perfectly obvious. The railways lack the mobility necessary for many branches of modern industry.

The recognition of their difficult position caused the railways to seek 'road powers,' and in 1929 several schemes were announced. In some cases the railway companies combined with municipalities or with private companies to run joint services of motor-buses on the road; in others schemes of part road, part rail traffic were initiated. Short suburban lines are hardest hit. In 1935 the Traffic Commissioners

estimated that the roads carried one-quarter of the goods traffic and two-fifths of the passengers. Britain is generally supposed to have the best-laid railway-tracks in the world. It would be a misfortune if they could not be restored to a full measure of usefulness.

That Britain is not seriously behindhand, compared with other nations, is shown by the fact that her long-distance runs are still the fastest in the world made by steam-hauled



THE DOVER-DUNKERQUE TRAIN-FERRY "TWICKENHAM"
By courtesy of the Southern Railway

trains. The "Coronation" between London and York has an average speed of over 70 m.p.h. This is exceeded only by Diesel engines on the American and German State Railways.

Three canal systems, the Grand Junction, the Regent, and the Warwick and Birmingham, were amalgamated as the Grand Union Canal Company in 1929, which was evidence that even the old barge canals had not given up in despair. Three new and important road bridges were made in the North of England, one over the Yorkshire Ouse at Boothferry, near the Humber, a fourth bridge over the Tyne at Gateshead-Newcastle, and a new bridge over the Tweed at Berwick. The railway companies instituted third-class sleepers in 1928, and partially restored the old pre-War excursion facilities; but they still did little to attract more

of the regular 'customers'—that is, season-ticket holders and the ordinary, regular passengers.

One of the ways in which Great Britain has endeavoured to keep abreast of modern conditions is by the establishment of the now well-known train-ferry which plys daily between Harwich, in Essex, and Zeebrugge, in Belgium. This service is suspended during the winter months, but a new service direct to Paris without break of bulk by way of Dover and Dunkerque has been instituted. Freight is carried by this means, but the ferry is chiefly used by passengers, to whom convenience and the saving in time are of greater consideration. The success of these ventures has encouraged the hope that in course of time a similar service may be instituted between some such port as Immingham on the British side and Esbjerg, in Denmark, or Göteborg (Gothenburg), in Sweden.

Ten years ago there was much talk of a Channel Tunnel; interest was then deflected towards the construction of the Mersey road tunnel (1934), and the international situation in more recent years has not been such as to encourage the revival of the Channel Tunnel schemes. But there are other evidences that the community is prepared for advances in many directions. Let it always be remembered that Britain lives to a great extent by her manufactures, her transport by land and water, and by her trade at home and abroad. Her 'captains of industry,' her 'leaders of democracy,' her workers of all grades and from all classes, need to take long views and to exercise a wide vision.

"Where there is no vision the people perish."

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